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# OPERATIONS MANUAL FOR THE INSPECTION WORKSTATION

NBSIR 88-3766

NBS  
PUBLICATIONS

April 21, 1988

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Howard T. Moncarz  
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# TABLE OF CONTENTS

	<u>Page</u>
I. <u>INTRODUCTION</u> . . . . .	1
1.   WHAT THIS MANUAL IS ABOUT . . . . .	1
2.   AUDIENCE . . . . .	1
3.   OVERVIEW . . . . .	1
II. <u>GENERAL DESCRIPTION OF THE IWS</u> . . . . .	3
1.   PHYSICAL LAYOUT . . . . .	3
1.1. <u>Coordinate Measuring Machine (CMM)</u> . . . . .	3
1.2. <u>Surface Roughness Instrument (SRI)</u> . . . . .	6
1.3. <u>Robot</u> . . . . .	6
1.4. <u>Material Handling System (MHS)</u> . . . . .	9
2.   MAIN MODES OF OPERATION . . . . .	9
2.1. <u>Integrated</u> . . . . .	12
2.2. <u>Stand-Alone</u> . . . . .	12
3.   THE IWS CONTROLLERS . . . . .	12
3.1. <u>What Is A Controller?</u> . . . . .	12
3.2. <u>Types Of Controllers</u> . . . . .	12
3.2.1. <u>Workstation Controller (WSC)</u> . . . . .	12
3.2.2. <u>Equipment Controllers</u> . . . . .	14
3.3. <u>How Controllers Are Connected</u> . . . . .	14
3.3.1. <u>Physical Connections</u> . . . . .	14
3.3.2. <u>Logical Connections</u> . . . . .	14
4.   CONTROLLER COMMANDS . . . . .	17
4.1. <u>Workstation Controller (WSC)</u> . . . . .	17
4.2. <u>Equipment Controllers</u> . . . . .	18
4.2.1. <u>CMMC Work Orders</u> . . . . .	18
4.2.2. <u>SRIC Work Orders</u> . . . . .	18
4.2.3. <u>IRC Work Orders</u> . . . . .	18
4.2.3.1. <u>For Robot</u> . . . . .	18
4.2.3.2. <u>For SRIC</u> . . . . .	19
5.   INSTALLATION . . . . .	19
III. <u>SAFETY CONSIDERATIONS</u> . . . . .	21
1.   BEFORE OPERATING THE IWS . . . . .	21
2.   ROBOT SAFETY . . . . .	21



IV.	<u>STARTING THE WORKSTATION</u>	25
1.	PROCEDURES FOR COMPUTER CONTROLLERS COLD START	25
1.1.	<u>Controller Cold Start Up</u>	25
1.1.1.	Turn Them On	25
1.1.2.	Boot Up Pascal	25
1.1.3.	Set The Date And Time	25
1.2.	<u>CMM Computer Cold Start Up</u>	26
2.	PROCEDURES FOR EQUIPMENT COLD START	26
2.1.	<u>Cold Start For The CMM</u>	26
2.1.1.	Turn It On	26
2.1.2.	Calibrate The PH9 Probe	26
2.1.2.1.	Execute The Calibration Program	26
2.1.2.2.	Activate Pendant Joysticks	28
2.1.2.3.	Move Probe Away From Table	28
2.1.2.4.	Switch To Absolute Mode	28
2.1.2.5.	Probe Calibration Positions	28
2.1.2.6.	Calibrate Zero Probe Position	28
2.1.2.7.	Calibrate Remaining Probe Positions	30
2.1.2.8.	Verify Probe Calibration	30
2.1.2.9.	Move To Zero Probe Orientation	30
2.2.	<u>Cold Start For The Robot</u>	30
2.2.1.	Turn It On	31
2.2.2.	Calibrate Robot Arm	31
2.2.2.1.	Switch to Arm Mode	31
2.2.2.2.	Move Arm To Calibration Position If Necessary	31
2.2.2.3.	Calibrate	35
2.2.3.	Calibrate Robot Track	35
2.2.3.1.	Switch To Track Mode	35
2.2.3.2.	Move Robot To Track Calibration Position	35
2.2.3.3.	Calibrate	35
2.2.4.	Load Robot Program (am_robot)	35
2.3.	<u>Cold Start For The SRI</u>	35
2.4.	<u>Cold Start For The ADI</u>	35
2.5.	<u>Safety Fence</u>	36
2.5.1.	Experimental Operation	36
2.5.2.	Unattended Operation	36
3.	PROCEDURES FOR EQUIPMENT WARM START	36
3.1.	<u>Warm Start For The CMM</u>	36
3.2.	<u>Warm Start For The Robot</u>	38
3.2.1.	Stop The Robot Program If Necessary	38
3.2.2.	Move Robot To Arm Calibration Position If Necessary	38
3.2.3.	Clear Serial Port	38
3.2.4.	Start The Robot Program	38
3.3.	<u>Warm Start For The SRI</u>	38



	<u>Page</u>
3.4. <u>Warm Start For The ADI</u> . . . . .	38
3.5. <u>Warm Start For The Safety Fence</u> . . . . .	38
4. PROCEDURES FOR EQUIPMENT CONTROLLERS WARM START . . . . .	39
4.1. <u>Starting The CMM Controller</u> . . . . .	39
4.2. <u>Starting The SRI Controller</u> . . . . .	39
4.3. <u>Starting The Robot Controller</u> . . . . .	39
5. PROCEDURES FOR WORKSTATION CONTROLLER WARM START . . . . .	39
5.1. <u>Integrated (Connected To Cell)</u> . . . . .	40
5.2. <u>Stand Alone (User Interface)</u> . . . . .	40
5.2.1. Starting The Execution Control System . . . . .	40
5.2.2. Workstation Synchronization . . . . .	43
5.2.3. Workstation Warm Start Up . . . . .	43
V. <u>OPERATING INSTRUCTIONS IN READY STATE</u> . . . . .	45
1. INTEGRATED MODE . . . . .	45
2. STAND ALONE . . . . .	45
2.1. <u>Equipment Controllers</u> . . . . .	45
2.2. <u>Operating Instructions For The WSC</u> . . . . .	45
2.2.1. Work Orders . . . . .	45
2.2.1.1. Creating Work Orders . . . . .	49
2.2.1.1.1. Automatic Creation Of Work Orders . . . . .	49
2.2.1.1.2. Manual Creation Of Work Orders . . . . .	49
2.2.1.2. Editing Work Orders . . . . .	49
2.2.1.2.1. Editing Work Order Action Data . . . . .	49
2.2.1.2.2. Editing Work Order Parameter Data . . . . .	49
2.2.1.3. Moving To Other Work Orders . . . . .	50
2.2.1.4. Deleting A Work Order . . . . .	50
2.2.1.5. Issuing Work Orders . . . . .	50
2.2.2. Warm Shut Down . . . . .	50
3. RESTARTING THE IWS . . . . .	50
3.1. <u>Restart Equipment</u> . . . . .	50
3.2. <u>Restart Controllers</u> . . . . .	51
VI. <u>SHUTTING DOWN THE WORKSTATION</u> . . . . .	53
1. SHUT DOWN STATES . . . . .	53
1.1. <u>Warm Shut Down</u> . . . . .	53
1.2. <u>Extended Warm Shut Down</u> . . . . .	53
1.3. <u>Cold Shut Down</u> . . . . .	53
1.4. <u>Extended Cold Shut Down</u> . . . . .	53
2. PROCEDURES FOR WARM SHUT DOWN . . . . .	53
2.1. <u>Workstation Controller</u> . . . . .	53



	<u>Page</u>
2.2. <u>Equipment Controllers</u> . . . . .	54
3. PROCEDURES FOR EXTENDED WARM SHUT DOWN . . . . .	54
3.1. <u>Computer Controllers</u> . . . . .	54
3.2. <u>Coordinate Measuring Machine</u> . . . . .	54
4. PROCEDURES FOR COLD SHUT DOWN . . . . .	54
4.1. <u>Workstation Controller</u> . . . . .	54
4.2. <u>Equipment Controllers</u> . . . . .	54
4.3. <u>Stop The Execution Control System</u> . . . . .	54
4.4. <u>Robot</u> . . . . .	55
4.4.1. Stop The Robot Program . . . . .	55
4.4.2. Move Robot To Arm Calibration Position . . . . .	55
4.4.3. Move Robot To Track Calibration Position . . . . .	55
4.5. <u>CMM</u> . . . . .	55
5. PROCEDURES FOR EXTENDED COLD SHUT DOWN . . . . .	55
5.1. <u>Computer Controllers</u> . . . . .	55
5.2. <u>Robot</u> . . . . .	55
5.3. <u>CMM</u> . . . . .	56
5.4. <u>SRI</u> . . . . .	56
5.5. <u>ADI</u> . . . . .	56
VII. <u>ERROR HANDLING</u> . . . . .	57
1. TYPES OF ERRORS . . . . .	57
2. CMM ERRORS . . . . .	57
2.1. <u>Missed Part</u> . . . . .	57
2.2. <u>Unexpected Touch</u> . . . . .	57
2.3. <u>Program Hangs</u> . . . . .	57
3. SRI ERRORS . . . . .	58
3.1. <u>SRI Display Changes To F's</u> . . . . .	58
3.2. <u>ADI Display Goes Off</u> . . . . .	58
3.3. <u>Program Hangs</u> . . . . .	58
4. ROBOT ERRORS . . . . .	58
4.1. <u>Move Error</u> . . . . .	58
4.2. <u>Program Hangs</u> . . . . .	58
5. WSC ERRORS . . . . .	58
5.1. <u>Process Plan Parsing Error</u> . . . . .	58
5.2. <u>Equipment Controllers Indicate Error</u> . . . . .	59
6. NETWORK ERRORS . . . . .	59
6.1. <u>Network Set Up Error</u> . . . . .	59
6.2. <u>During Operations</u> . . . . .	59
7. DATA SERVER ERRORS . . . . .	59



	<u>Page</u>
7.1. <u>Data Files Not Found</u> . . . . .	59
7.2. <u>AMRF Data System Indicates Error</u> . . . . .	59
VIII. <u>DATA PREPARATION</u> . . . . .	61
1. CREATING AND/OR EDITING DATA FILES . . . . .	61
1.1. <u>Who Should Do It</u> . . . . .	61
1.2. <u>The Editor</u> . . . . .	61
2. INTERNAL DATA STRUCTURES . . . . .	62
<u>GLOSSARY</u> . . . . .	63
<u>APPENDICES</u> . . . . .	69
A. IWS DOCUMENTATION LIST . . . . .	69
B. OPERATIONS REFERENCE GUIDE . . . . .	71
1. STARTING THE INSPECTION WORKSTATION . . . . .	71
2. OPERATING THE INSPECTION WORKSTATION STAND- ALONE . . . . .	72
3. RESTARTING THE INSPECTION WORKSTATION . . . . .	72
4. SHUTTING DOWN THE INSPECTION WORKSTATION . . . . .	73
<u>REFERENCES</u> . . . . .	75
READER COMMENT FORM . . . . .	77



# LIST OF FIGURES

	<u>Page</u>
Figure 1 -- Floor Plan of the AMRF . . . . .	4
Figure 2 -- Physical Layout of IWS . . . . .	5
Figure 3 -- Surface Roughness Instrument . . . . .	7
Figure 4 -- Automatic Dial Indicator . . . . .	8
Figure 5 -- Robot Teach Pendant . . . . .	10
Figure 6 -- Safety Fence . . . . .	11
Figure 7 -- Controller Hierarchy . . . . .	13
Figure 8 -- Physical Architecture of the IWS . . . . .	15
Figure 9 -- Logical Architecture of the IWS . . . . .	16
Figure 10 -- CMM Control Panel . . . . .	27
Figure 11 -- CMM Pendant . . . . .	29
Figure 12 -- Robot Control Locations . . . . .	32
Figure 13 -- Robot Control Panel . . . . .	33
Figure 14 -- Robot Display After System Software Loaded . . . . .	34
Figure 15 -- CMM Origin . . . . .	37
Figure 16 -- Robot Display When A Program Is Running . . . . .	41
Figure 17 -- WSC Operating Options . . . . .	42
Figure 18 -- Tray 510 . . . . .	46
Figure 19 -- Tray 520 . . . . .	47
Figure 20 -- Tray 530 . . . . .	48



# OPERATIONS MANUAL FOR THE INSPECTION WORKSTATION

## I. INTRODUCTION

### 1. WHAT THIS MANUAL IS ABOUT

The main purpose of this manual is to explain how to operate the Inspection Workstation (IWS).

The IWS inspects parts delivered to it by the AMRF Material Handling System. The current equipment at the IWS allows two types of part inspection: dimensional inspection and measurement of surface finish.

### 2. AUDIENCE

This manual is intended to be used by anyone who needs to operate the IWS--whether the IWS is integrated to the AMRF and accepting commands from the Cell, or whether it is in stand-alone mode and accepting commands directly from the operator.

No specialized training in computers or automation is required. The minimum requirement is that the operator be familiar with machine shop operations.

### 3. OVERVIEW

Chapter II gives an overall description of the IWS. The material covered in this chapter is not required to start up and run this workstation. However, the operator is encouraged to read this chapter to gain a better understanding of the IWS--in order to make fuller use of its capabilities.

Chapter III is a short tutorial on safety considerations in operating the IWS. All operators should read and understand this chapter before starting up the IWS.

Chapters IV, V, and VI explain the operation of the IWS--starting it up, operating it, and finally, shutting it down. Under normal operation, these chapters contain all the information necessary to operate the IWS.

Chapter VII describes possible errors that can occur during operation, and explains how to deal with each one.

Finally, Chapter VIII explains data preparation. Currently, data preparation or editing should not be done by IWS operators. However, this chapter is included for completeness; to give a flavor of the type of data that the IWS uses.



The information in the Glossary, Appendices, and References is not required to operate the IWS. However, the operator may find this information useful.

The glossary defines terminology used in this manual.

Appendix A lists all the documents included in the complete IWS documentation. For an understanding of the IWS beyond the material covered in this manual, refer to the proper document listed in this appendix.

In addition to the IWS documentation, other documents (e.g. the equipment user manuals) that could be helpful to the IWS operator are listed in the References section.

Appendix B consists of three condensed reference guides of the starting, ready state, and shut down procedures.

Finally, an error report/reader comment form is provided for the operator to give feedback on the manual, so that improvements can be made in the future.



## II. GENERAL DESCRIPTION OF THE IWS

The information contained in this chapter is necessary for the operator who wants to gain a general understanding of the IWS architecture and equipment configuration in order to make full use of its capabilities. This chapter can be skipped, however, if the operator only wants to run the workstation in its simplest mode of operation.

### 1. PHYSICAL LAYOUT

The Inspection Workstation is located in the temperature controlled room in the southwest corner of the AMRF shop floor. Figure 1 is a diagram of the entire AMRF. The IWS is located in the bottom left of this figure.

The physical layout of the IWS is shown in Figure 2. A cart carrying a tray of parts to be inspected comes into the IWS along the track shown in this figure. The tray is automatically delivered to the tray transfer station that is located under the robot. (The robot is mounted on a gantry above the IWS.)

There are three major pieces of equipment in the IWS: the Coordinate Measuring Machine (CMM), the Surface Roughness Instrument (SRI), and the Robot. (Note that in this document, the 'R' in 'Robot' is capitalized when referring to the IWS Robot.) The equipment at the IWS is described below.

#### 1.1. Coordinate Measuring Machine (CMM)

The CMM is used to measure the dimensional tolerances of a part. To enable very accurate measurements, the temperature within the IWS is maintained at twenty degrees Celsius. The particular CMM used is known as a horizontal arm CMM, since it consists of a horizontal arm that moves vertically.

The part to be measured is placed on the table of the CMM. This table has three degrees of freedom in the horizontal plane--two translational degrees of freedom perpendicular to each other and one rotational degree of freedom about an axis through the center of the table. A probe is mounted on the end of the arm. The particular probe used for the IWS is a PH9 type probe. This probe has an additional two rotational degrees of freedom about the arm.

The probe is a force sensitive mechanism that registers a touch if its synthetic ruby tip encounters a small force. This force is adjustable and is held at about five grams for normal IWS operation. At this force level, most parts can be accurately measured while the part is secured on the table by its own



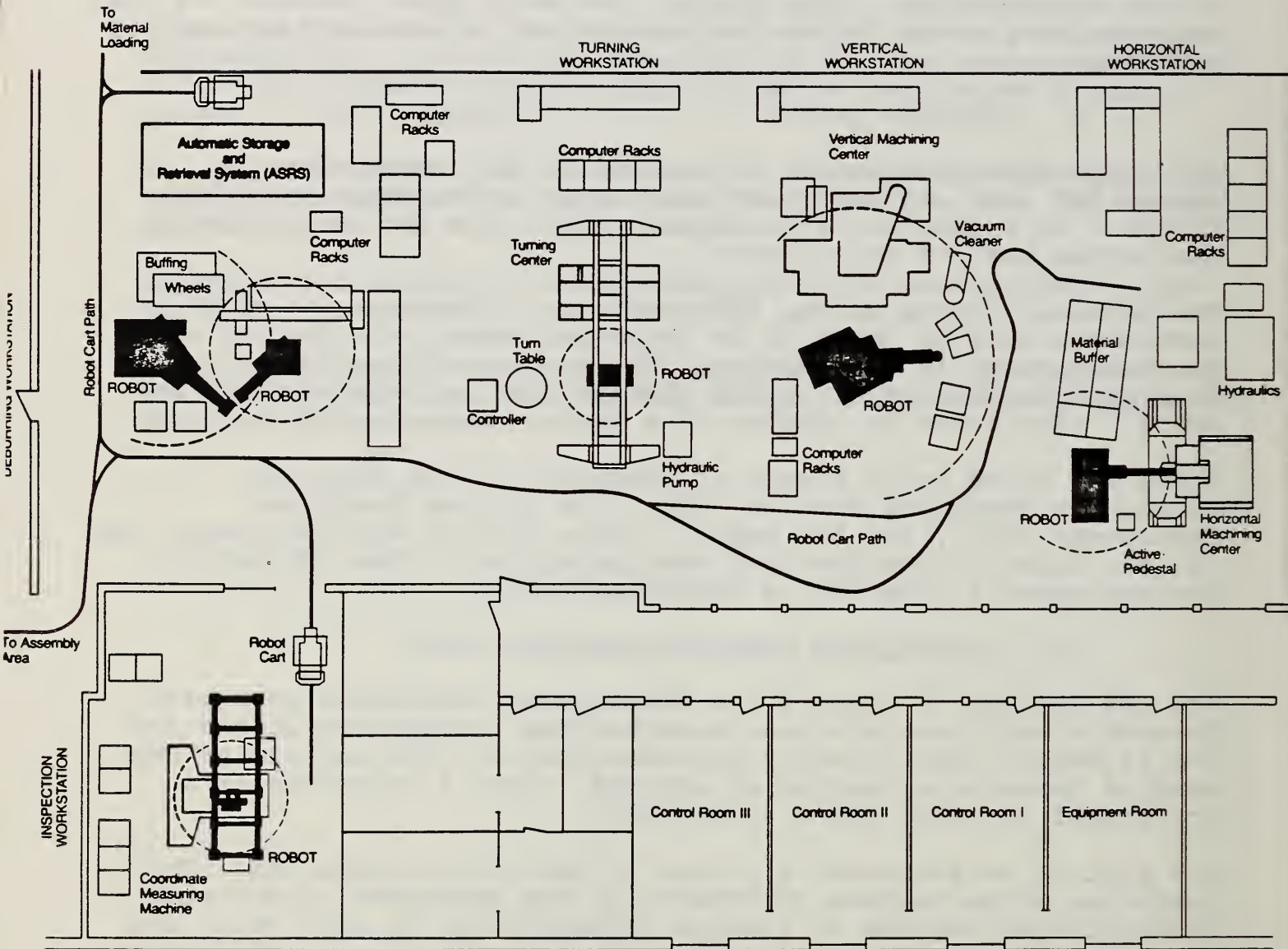


Figure 1. Floor Plan of the AMRF



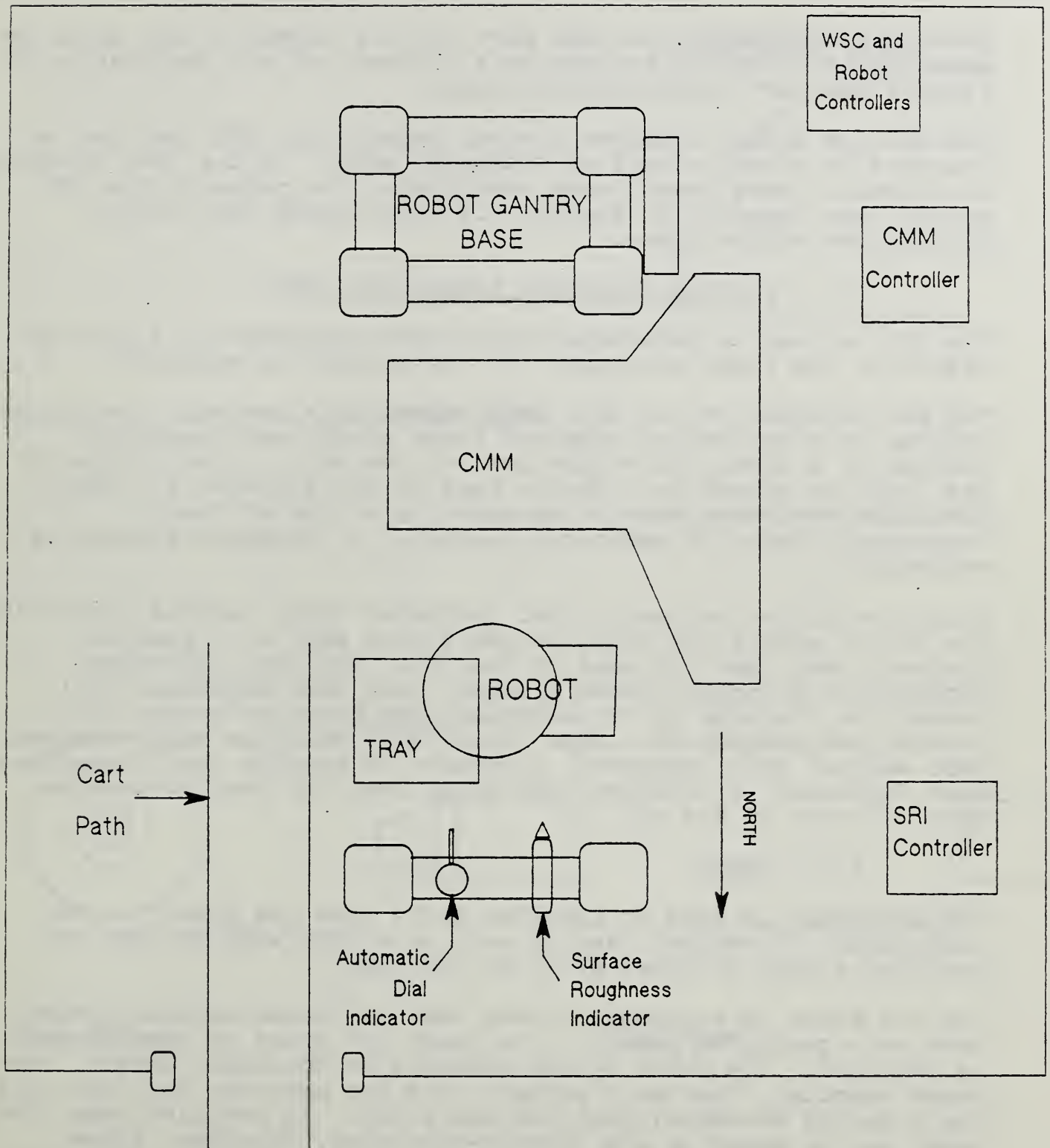


Figure 2. Physical Layout of IWS



force due to gravity. If the part is very light, it can still be measured if it can be mounted on a fixture and the combination of fixture and part placed on the table.

The CMM has direct computer control capability (DCC) and can be operated in either manual or automatic mode. In the IWS, it works in automatic mode except when positioning the probe to the CMM Origin (see Chapter IV, Section 3.1) and during the initial calibration of the probe.

### 1.2. Surface Roughness Instrument (SRI)

The SRI is used to determine the surface roughness of a part by measuring the light scattered off the surface in question.

The SRI consists of two main components: an electronic controller mounted in a box and an infrared light source and detectors mounted in a tube (called the head of the SRI). (See Figure 3.) The light is shined in a narrow beam on the surface of a part. The light scattered back is measured by a line of twenty detectors. Based on empirical analysis, a roughness average is estimated.

Additionally, an automatic dial indicator (ADI) is used along with the SRI to enable the Robot to position a part at a precise distance away from the head of the SRI. The dial indicator consists of a spring loaded plunger, that when depressed will record the distance it is depressed, and the electronics to control and monitor it. (See Figure 4.) When the Robot presses a part against this indicator, a reading of how far the plunger has been depressed is recorded, and later used for positioning the part in front of the SRI.

### 1.3. Robot

The IWS Robot is used to transfer parts from one place in the workstation to another, and to work as a unit with the SRI to position a part in front of it as required.

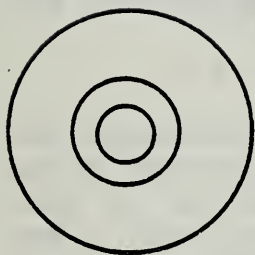
The IWS Robot is a standard robot that is custom mounted upside down on a gantry to permit it to reach any place in the IWS that is required. The Robot system consists of the Robot itself, the Robot computer, the teach pendant, and the monitor. The Robot has two modes of movement: position and track. In position mode, the Robot can be moved at six joints--the waist, shoulder, elbow, wrist roll, wrist flex, and hand roll. In track mode, the Robot can be moved along the gantry track. The Robot cannot move in both modes simultaneously.



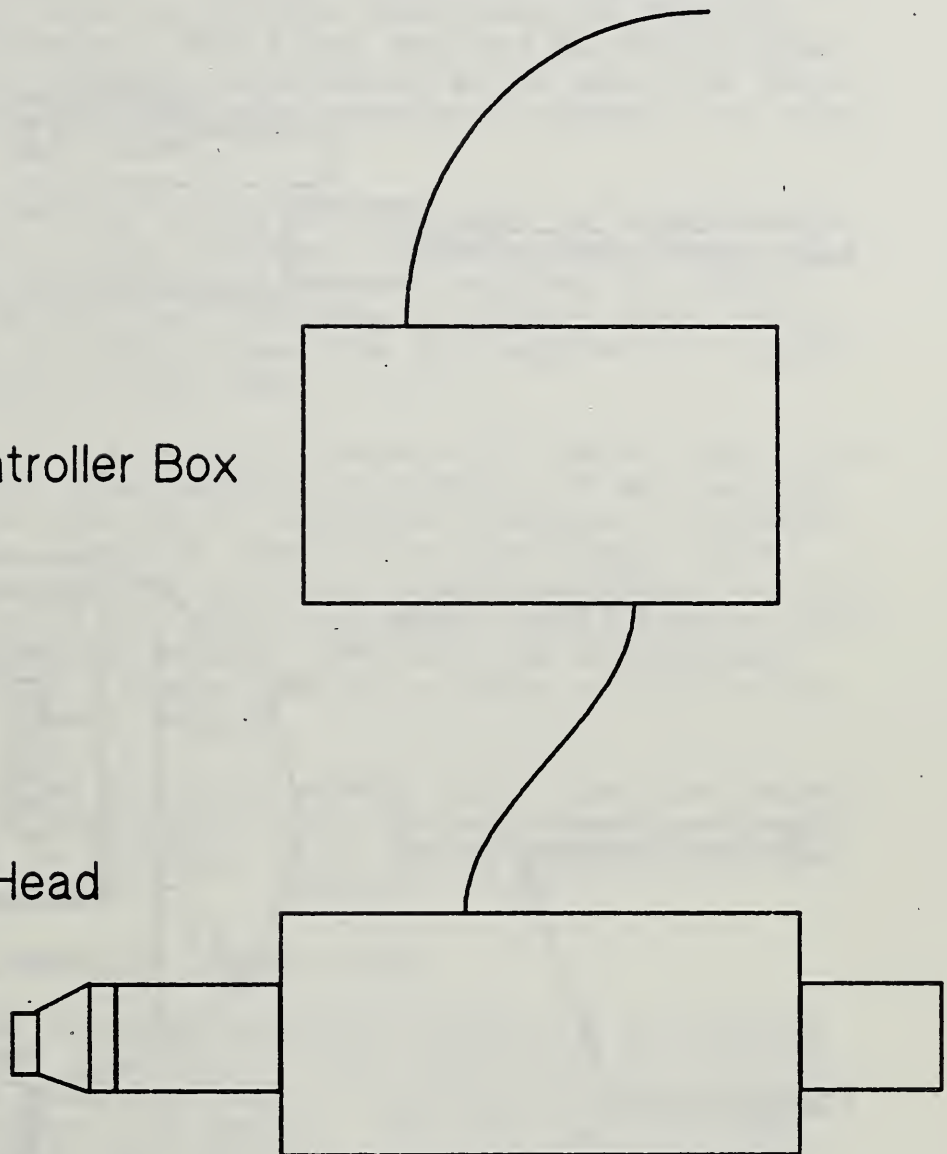
To SRI Controller

Controller Box

Head



Front View



Side View

Figure 3. Surface Roughness Instrument



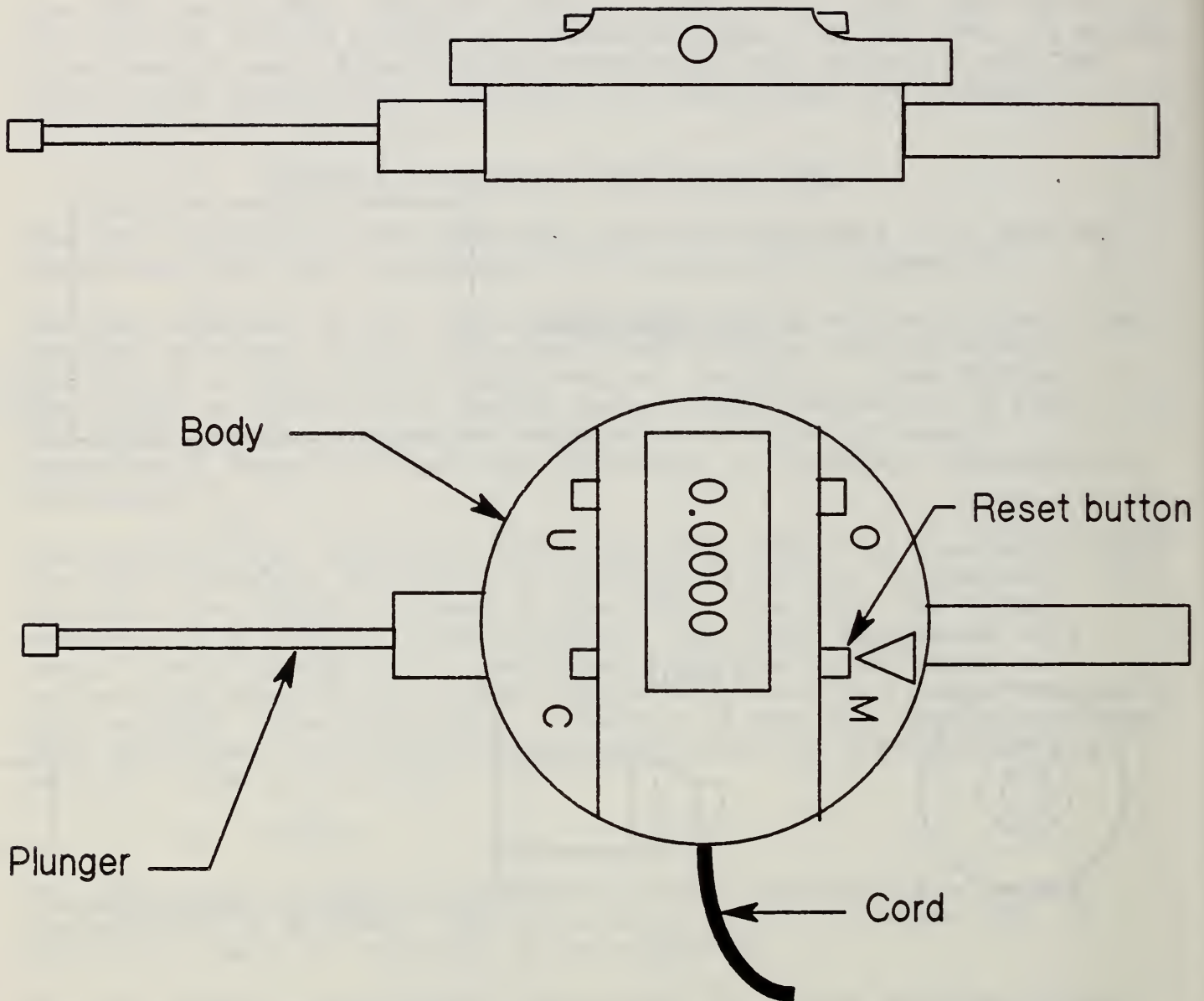


Figure 4. Automatic Dial Indicator



The arm is capable of lifting up to 50 pounds, and has a span of 40 inches. The gantry axis is 72 inches long. The gripper has a maximum span of 6 inches and the gripper pads move in straight lines maintaining parallelism. The force applied to the gripper is determined by the air pressure available; at 60 psi it's about 40 pounds. It is not adjustable under automated control, so that any fragile parts will be crushed.

The robot has its own computer built into it that is considered part of the Robot itself. This computer contains two floppy disk drives; one is used for the AR Smart system required for Robot operation. The other is for user programs. In particular, this drive contains the program that allows the HP computer to control the Robot and interface it to the IWS.

A teach pendant (Figure 5) is used to operate the Robot when it is not hooked up to the IWS. The pendant includes a 20 key keypad, with 4 color-coded modes, giving 80 different commands available. On the same pendant is a joystick control for the Robot, with three degrees of freedom available at any one time. That is, the joystick can do x, y, and z in 'position' mode, or it can do roll, pitch, and yaw in 'orientation' mode. Position or orientation mode is chosen by a switch. There is also a motor on/off button and a program run/stop rocker switch.

Surrounding the Robot is an electric safety fence that can detect if anyone comes into the space that the Robot can reach. If so, the controls can be set to sound an alarm or to immediately turn off the Robot. (See Figure 6.)

#### 1.4. Material Handling System (MHS)

The function of the AMRF Material Handling System is to deliver parts throughout the AMRF as needed. The components of the MHS used by the IWS include the tray table, an interlock mechanism, and a cart used to transport the parts. The only part of this system under the control of the IWS is the interlock mechanism. The IWS sends a command to this mechanism which either allows or prevents the MHS from taking control over the tray. (For further details of the MHS, see Reference 8.)

## 2. MAIN MODES OF OPERATION

The IWS operates in two main modes of operation--either integrated or stand-alone. These are described below.



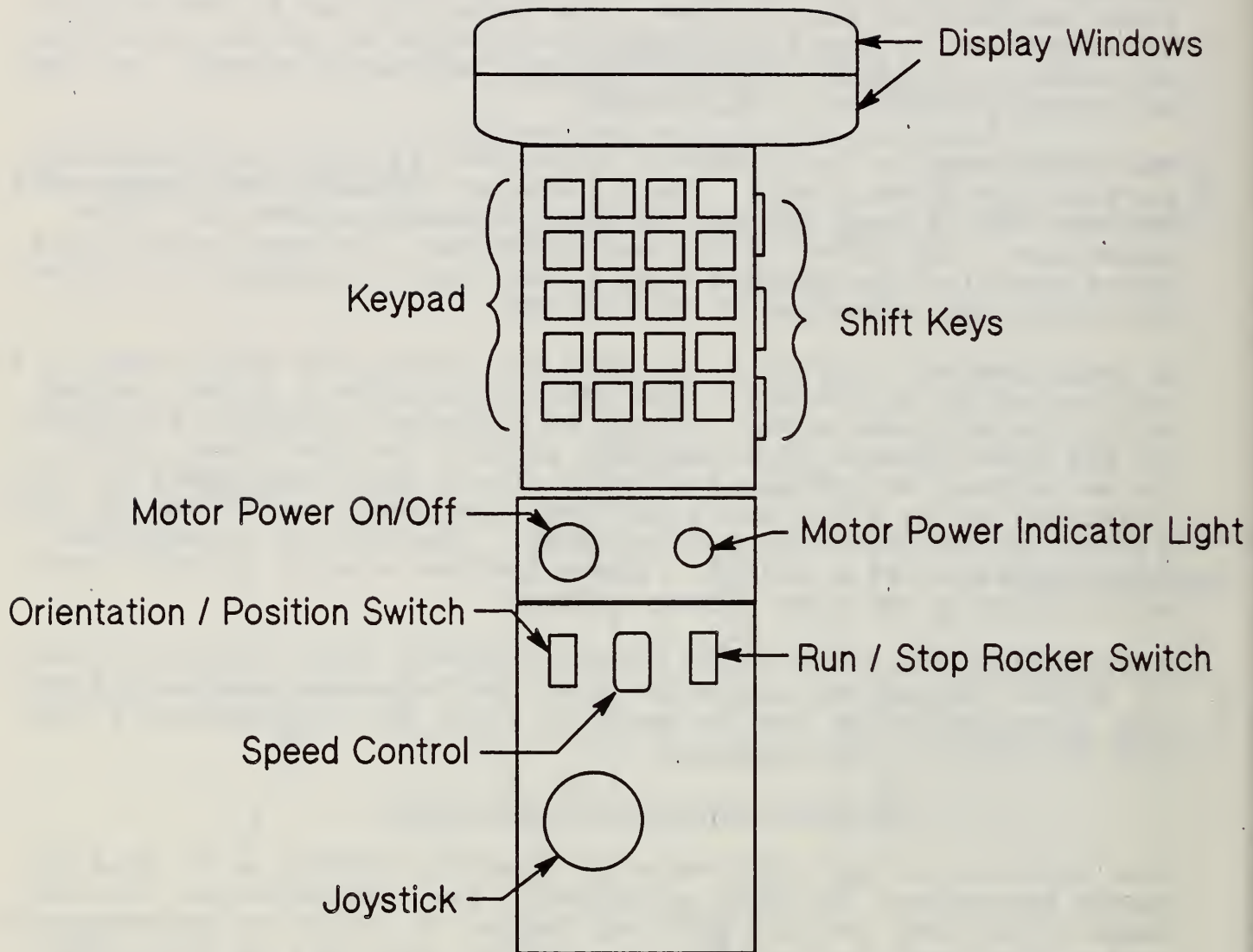
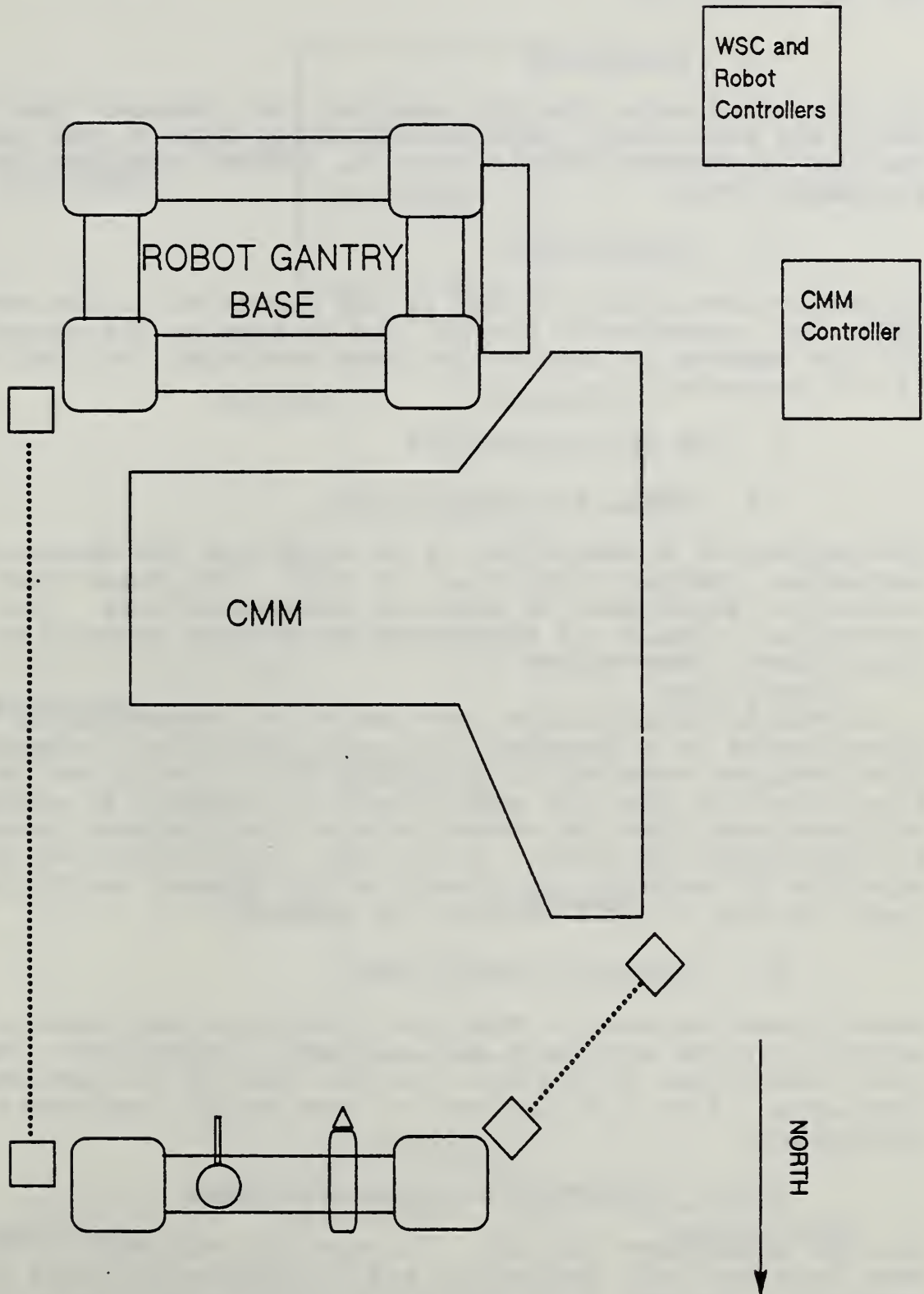


Figure 5. Robot Teach Pendant





Electric eye fence shown by .....

Figure 6. Safety Fence.



### 2.1. Integrated

In integrated mode, the IWS receives its commands from the AMRF Cell, and continually reports its status back to the Cell. Once the IWS is started in this mode, no further operator action is required.

### 2.2. Stand-Alone

In stand-alone mode, the IWS is not connected to the rest of the AMRF. All commands to the IWS are entered by the operator. The IWS can operate in stand-alone mode even when the rest of the AMRF is not operating.

## 3. THE IWS CONTROLLERS

### 3.1. What Is A Controller?

The purpose of a controller is to supervise the operation of a mechanism, another controller, or both. The thing that the controller supervises is known as its subordinate. The controller, itself, is supervised by another controller called its supervisor. (See Figure 7.)

A controller accomplishes its mission by communicating to its subordinates in a language that each subordinate understands. This language consists of commands from a controller to its subordinate of what the subordinate is supposed to accomplish and statuses back from the subordinate of the progress towards accomplishing its tasks. In the IWS, each controller is on a separate HP computer and communication between controllers takes place through a local workstation network.

### 3.2. Types Of Controllers

Controllers are used in the IWS to regulate and monitor the activity of the equipment and equipment controllers. There are four controllers at the IWS; one for each of the equipment systems (Sections 1.1 to 1.3) and one for the overall workstation controller.

#### 3.2.1. Workstation Controller (WSC)

The WSC supervises the IWS. It receives commands in integrated mode from the Cell Controller and in stand-alone mode from an operator. The WSC is in charge of coordinating the activity of the IWS by sending commands to the equipment controllers and monitoring their return statuses.



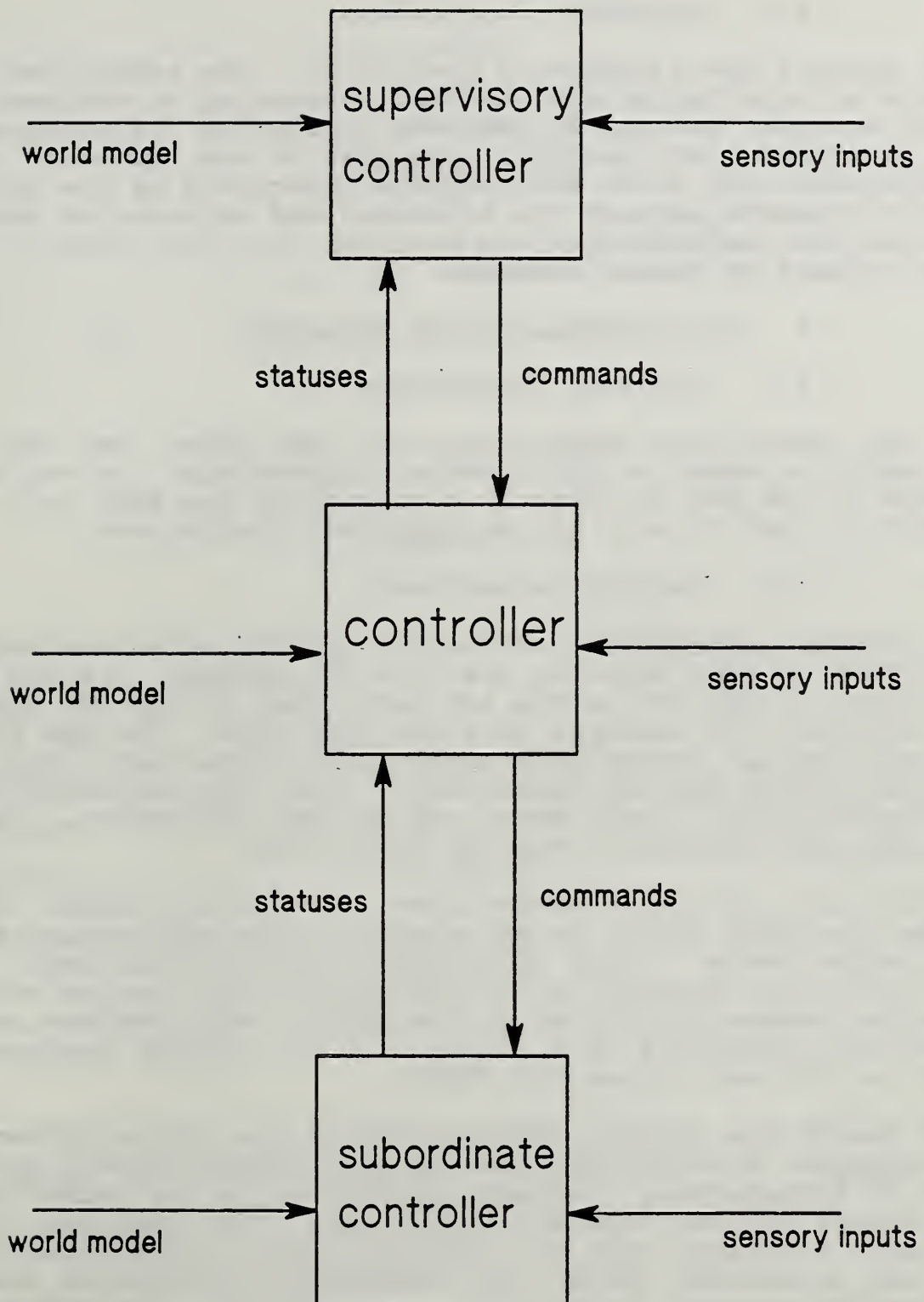


Figure 7. Controller Hierarchy



### 3.2.2. Equipment Controllers

Each machine has a dedicated controller. The controller is in charge of interfacing with the WSC, executing an equipment work order command, and controlling and monitoring the assigned device. The controllers are directly connected to the equipment and communicate with it in the language understood by the device. The only difference between the equipment and workstation controllers is that the feedback from the machines is in the form of sensory data instead of status messages.

### 3.3. How Controllers Are Connected

#### 3.3.1. Physical Connections

All the controllers communicate with each other (and the rest of the AMRF) by means of RS232 serial connections. As can be seen in Figure 8, the WSC is directly connected to the AMRF Cell Controller and to each of the equipment controllers.

#### 3.3.2. Logical Connections

The logical architecture of the IWS specifies how controllers are connected to each other by the flow of commands. As can be seen in Figure 9, the WSC is the top most level of the IWS hierarchy and receives its commands from the AMRF Cell. The CMM and Robot Controllers are subordinate controllers to the WSC. The CMM is directly below the CMM Controller. Under the Inspection Robot Controller (IRC) is the Robot and the SRI Controller. The SRI and the ADI are directed by the SRI Controller.

Additionally, all four controllers can directly access (in logical terms) the AMRF IMDAS, to get whatever data each separate controller needs. IMDAS (Integrated Manufacturing Data Administration System) is the distributed data system which provides common interfaces to the AMRF's user programs and underlying databases [B.9, B.10]. In the current implementation, only the WSC can access the IMDAS.

Even though the logical architecture of the IWS is different from its physical architecture, the network communications system takes care of transferring commands and data along the paths shown in the figure for the logical architecture. For instance, to transfer a command from the Inspection Robot Controller (IRC) to the SRI Controller (SRIC), the command is transferred from the IRC to the WSC computer to the SRIC. Effectively, the command is transferred from the IRC to the SRIC, even though in actuality it is relayed by the WSC computer. The roundabout path is chosen by the network communications system, and can be ignored by the



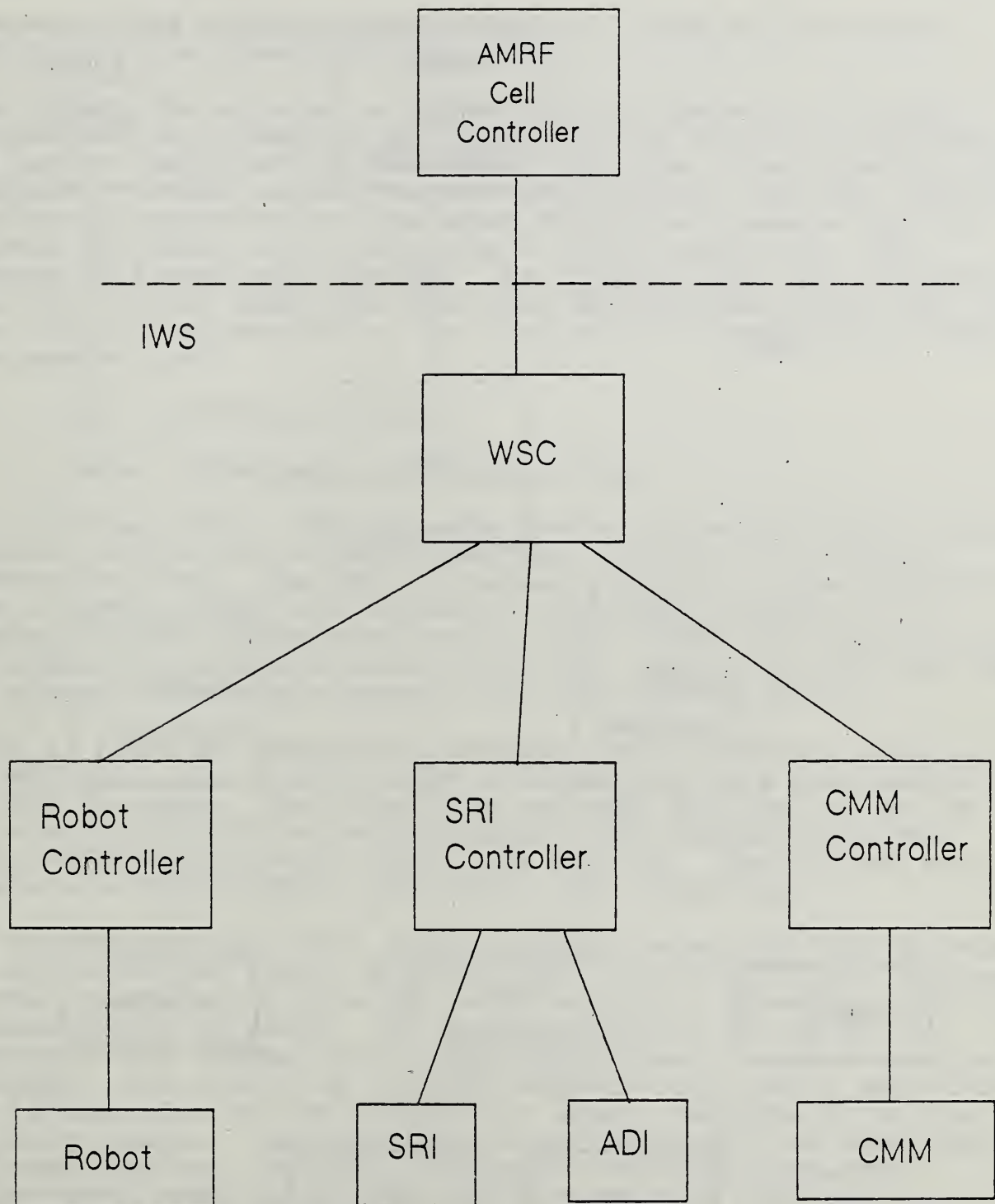


Figure 8. Physical Architecture of the IWS



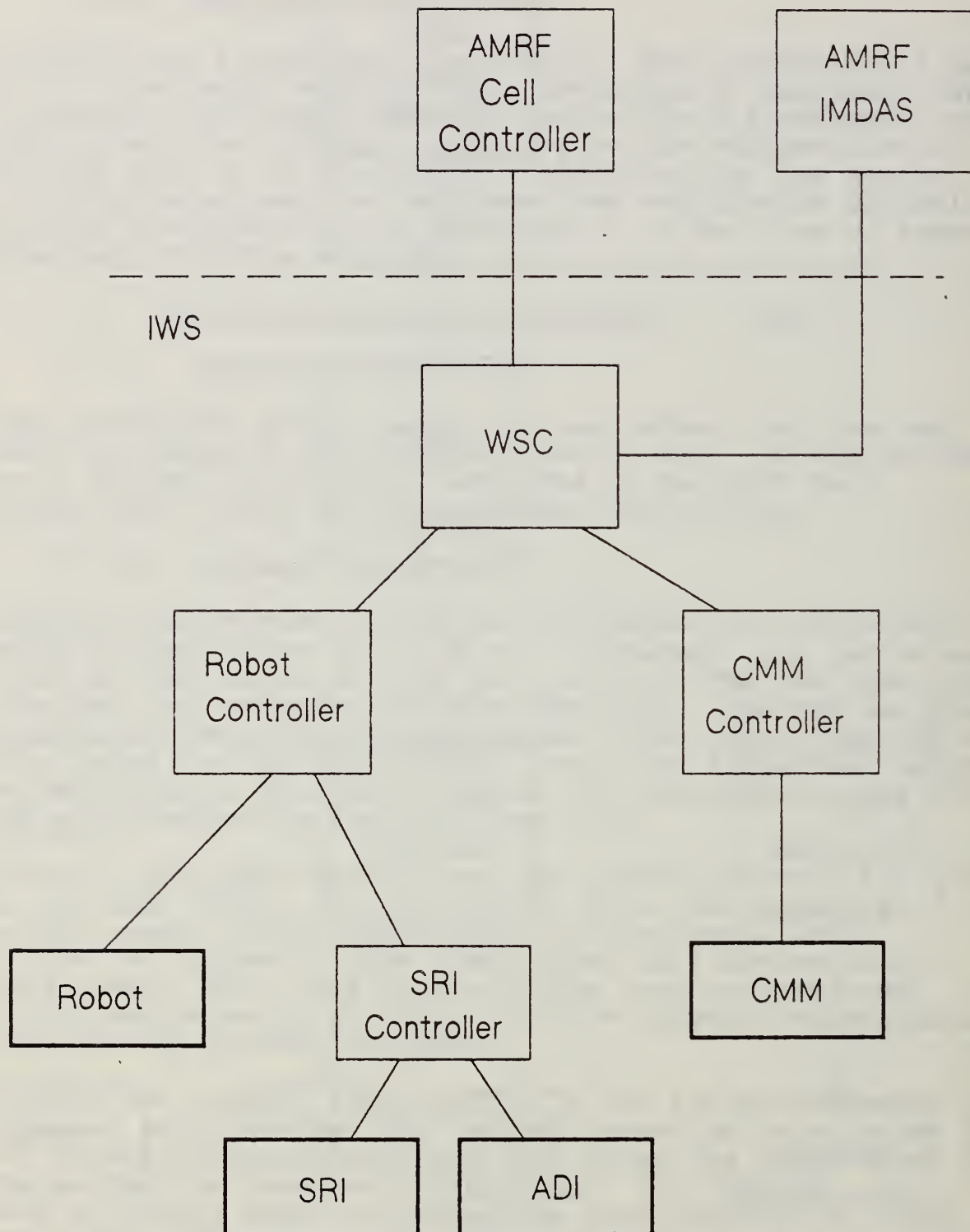


Figure 9. Logical Architecture of the IWS



operator. The operator should think in terms of the logical architecture to understand the system.

Even though the physical architecture may change in a future implementation to improve the efficiency of the data transfers, the logical architecture can remain the same if so chosen by the designer. In the current logical architecture, the SRI Controller is directly connected to the Robot Controller because the two operate together, as if they were a single mechanism, when inspecting a part with the SRI. To connect these two controllers together, rather than have them both subordinate to the WSC, is a more natural implementation and results in a considerably simpler programming task.

#### 4. CONTROLLER COMMANDS

##### 4.1. Workstation Controller (WSC)

As indicated above, Cell commands can be issued to the WSC from the Cell Controller in integrated mode or from the user in stand-alone mode. The WSC initiates operation of the workstation from a state called cold shutdown by issuing a sequence of commands to its subordinate controllers. This is required to put the IWS into the proper state (the ready state), so that the WSC can accept inspection commands from the Cell (or user).

There is a set of transition commands used to set up and shut down the WSC and a set of work order commands that are permissible once the WSC is ready. The transition commands utilized to set up the WSC are SYNCHRONIZE and WARM\_STARTUP, and WARM\_SHUTDOWN and COLD\_SHUTDOWN are used to shut down the WSC. The current work orders are RECEIVE\_TRAY, SHIP\_TRAY, and INSPECT\_LOT.

The RECEIVE\_TRAY and SHIP\_TRAY commands prepare the IWS to receive or ship a tray of parts, respectively. The INSPECT\_LOT work order is the input command from the Cell Controller directing the WSC to inspect a tray of parts. It is the objective of the WSC to decompose that command into a set of equipment level work order commands. The resulting group of machine work orders constitutes the process plan at the workstation level, referred to as the operation sheet. The individual work orders will be discussed in the next section. Usually, each work order has arguments - (parameters) associated with it; however, they will not be discussed in this document.



## 4.2. Equipment Controllers

The CMM, SRI, and Robot each have their own controller--the CMMC, SRIC, and IRC, respectively. The CMMC and IRC receive orders from the Workstation Controller and supervise the operation of their appointed machine. The SRIC receives its orders from the IRC and commands the SRI and ADI. Following is a description of the work orders that are currently supported by the IWS equipment controllers. It is not necessary to be familiar with this set of commands unless the operator is interested in generating new operation sheets.

### 4.2.1. CMMC Work Orders

There are two work orders that can be sent to the CMMC: LOAD\_DATA and INSPECT. The LOAD\_DATA order is used to direct the CMMC to retrieve the required part and inspection plan data. The function of the INSPECT order is to command the CMMC to measure the dimensional tolerances of the given part.

### 4.2.2. SRIC Work Orders

In the present IWS configuration, the SRIC is under the control of the IRC; therefore, the SRIC work orders are issued by the IRC and not by the WSC. These work orders are LOAD\_DATA, READ\_DIAL, and INSPECT\_PART. LOAD\_DATA directs the SRIC to retrieve the required part and inspection plan data. READ\_DIAL obtains a dial reading from the ADI. INSPECT tells the SRIC to begin the SRI inspection.

### 4.2.3. IRC Work Orders

WSC work orders to the IRC contain commands specific to the Robot, commands that are executed by the IRC and the SRIC together, and commands that are passed on by the IRC to be executed by the SRIC itself. Commands executed by the Robot itself are discussed in the next section. Commands that are executed by both the IRC and SRIC or the SRIC alone are discussed in the section following that one.

#### 4.2.3.1. For Robot

The first work order that the IRC must receive is LOAD\_DATA--to command the IRC to retrieve the data that it requires to operate.

The other Robot specific work orders are ACQUIRE, CLEAR, MOVE, RELEASE, and TRANSFER. These commands were originally defined for the Horizontal Workstation [7] and were adapted for the IWS. The ACQUIRE command is used to direct the Robot to grasp a part at a given location. Conversely, the function of the RELEASE order is



to instruct the Robot to release the part and end up at a given point. The CLEAR command is similar to the RELEASE command, except that the Robot is first directed to go to a particular point before it releases the part. The MOVE order commands the Robot to move the part from its current location to a specified destination, but not release it. The TRANSFER work order is a higher level combination of ACQUIRE, MOVE, and RELEASE. If the Robot is holding the part to be transferred, the ACQUIRE portion is ignored.

#### 4.2.3.2. For SRIC

The work orders employed to operate the SRI through the IRC are LOAD\_SRI\_DATA, GET\_DIAL\_READING, and INSPECT\_WITH\_SRI. These three work orders are sent from the WSC to the IRC. The first, LOAD\_SRI\_DATA is passed on to the SRIC. (The command to the SRIC is LOAD\_DATA.) The latter two commands require both Robot move commands and commands to the SRIC. The GET\_DIAL\_READING command is used to determine the part offset relative to the Robot grippers so that the part can be positioned correctly in front of the SRI head. This command requires the Robot to move the part surface up to the ADI, and then issue the READ\_DIAL work order to the SRIC. The INSPECT\_WITH\_SRI command directs the Robot to move the part surface up to the SRI and then issue the command, INSPECT\_PART, to the SRIC.

### 5. INSTALLATION

The IWS controllers and equipment are currently installed and configured. Note that the configuration and switch settings should not be changed under normal operating conditions.







### III. SAFETY CONSIDERATIONS

#### 1. BEFORE OPERATING THE IWS

Before operating the IWS you must first complete an orientation course given by a qualified IWS staff member that includes safety information and instruction for operating the IWS.

#### 2. ROBOT SAFETY

If you will be operating the IWS Robot you must thoroughly understand the information presented here. People who are incidentally in the area can be governed by a simple rule: stay behind the light fence.

The problem of safety around a robot is not a simple one. It will be necessary to get close to the IWS Robot at times and especially during the teaching and calibration phases. Particular attention has to be taken when operating the Robot, even when you have the teach pendant in your hand and have your fingers over the emergency motors off button. You need to understand the system and how it will react to your inputs. Only with experience can you develop the skill required to be comfortable in handling the Robot.

The rest of this section applies specifically to the "American Robot" (now American Cynflex) Merlin robot on the gantry frame in the Inspection Workstation.

This Robot has several modes of operation. The choices include: machine 0 or 1, elbow mode 0 or 1, move mode 0 or 1, position or orientation, and the three axes.

Machine 0 is the 6-axis Robot, and machine 1 is the gantry, which has just one axis. These are changed by the green shift of the key labeled MVM (it has no green label).

Elbow mode is selected by the ELM key, followed by a 0 or 1 argument. It can also be included in a program. Elbow mode 0 is elbow down for our system; it is never used. Unfortunately, elbow mode 0 is the default of the system. Elbow mode is the nastiest trick that this Robot can play on you. The trouble is that the Robot we have is hung upside down from the gantry. This means that we usually work in the non-default elbow mode, mode 1, which keeps our elbow up. The canned programs all have a declaration of ELM 1 near the beginning, so when they are run the Robot will work properly. However, ELM is cleared when you Clear Program, so you can get an unexpected elbow shift, which is a thrust of the hand forward like the lunge of a fencer. Note that elbow mode only



applies when the machine is in move mode 1, the straight line motion. This is a good reason to use move mode 0 as often as possible.

Move mode is selected by the key MVM, and a 0 or 1 argument. Move mode 0 is "joint-coordinated" motion, where each joint moves separately. From the pendant, this means that each joystick direction controls an axis independently. In a program, it means that the arm "swings" through motions smoothly, but not on a precise path. Move mode 0 is less likely to produce move errors in a program, since it is less likely to go through a "forbidden" zone, e.g. the Robot's own base. For teaching points, move mode 1 is more commonly used, since it gives moves that are definitely predictable in a right-angle coordinate system. For example, when a part is being placed on a table, a single joystick move can move the point closer to the table without changing the orientation of the part.

Position or orientation is a choice that only applies to joystick motions. In move mode 0 (joint-coordinated), "Position" means that the joystick moves are related to the first three axes (waist, shoulder and elbow), and "Orientation" means that they are related to the three final axes (wrist roll, wrist flex, and hand roll). In move mode 1, "Position" means that the joystick moves are straight lines at right angles to each other. "Orientation" should mean that the joystick controls three rotations, one about each orthogonal axis. It doesn't seem to work quite that simply; the axes of rotation are all different, but not orthogonal.

The common teaching mode is machine 0, elbow mode 1, move mode 1. In this circumstance, the position movements labeled X, Y and Z are the absolute directions: X is East-West, Y is North-South, and Z is Up-Down. (This is if frame 0 and tool 0 are set.)

The problem relating to safety is primarily how to predict what will happen when you issue a command. ("Command" can mean either a keyboard or joystick action.) Practice with the joystick is the best way of learning what it does. Unexpected moves from keyboard commands are best avoided by learning the combinations likely to cause them. These combinations are primarily: move mode 1 with elbow mode 1, moving through the wrist straight orientation in move mode 1, forgetting that a frame or tool is set and going the wrong way with the joystick (i.e. Down instead of North), clearing a program in move mode 1, moving to a point relatively instead of absolutely (on either machine), and moving the wrong machine.

Other guidelines which should be followed:

1. Only one person inside the fence at a time (when the Robot is



active); that person should be using the pendant and be in complete charge of the Robot's actions.

2. Before issuing commands which may cause large motions (e.g., MOV, ELM, MVM) step back from the Robot; preferably outside the fence.

3. Keep the speed low--this means both the wheel on the pendant and the programmed SPD; they are independent. You can't keep the MOV slow by turning down the rheostat.

4. THINK before you move: At least mentally check the frame set, the tool set, the move mode setting, the elbow mode setting, and the speed. It doesn't hurt to issue a redundant command to be sure of these settings. (As long as it's into MVM 0; the change to MVM 1 or ELM 1 can be very hazardous.)

The Robot shouldn't be impossible to stop; there is a collision sensor which monitors the Robot's arm. If sufficient force is applied to the arm, the programmed position and the present position will be unacceptably far apart and the Robot will shut down. Punching the arm with a fist seems to be the most effective way to activate the collision detector. Warning: the detector is quite tough to activate; DO NOT depend on this to avoid injury. The quickest way to stop a disastrous move is to shut down the motors. The pendant's red button will usually be closest to the main operator; another button is on the front panel. Turning on the fence (which will often be off during teach operations) and running your hand through the light fence is the quickest way to shut down the Robot from the side of the room away from the control panel. Please note that pressing the red button on the front panel or activating the fence stops the robot's motion immediately by applying a brake to it. Pressing the stop button on the pendant merely turns the robot motor off, and the arm will drift slightly before coming to a stop.

For a more comprehensive description of operating the Robot, see the Merlin Robot System Operators and User Guide [3].







#### IV. STARTING THE WORKSTATION

A number of procedures must be done in the correct order to start up the IWS. When all of the IWS equipment and computers have been shut down for an extended period of time, all of the cold start up procedures described in this chapter must be done. First the computer controllers must be started and then the equipment itself must be brought to a cold start. When the IWS has to be restarted or when cold start is completed, the equipment controllers and equipment must be warm started. Finally, after the Workstation Controller has completed warm start up, the IWS is ready for operation.

This chapter describes the required start up procedures and the equipment calibration procedures in detail. Refer to Appendix B.1. for a quick reference guide on starting the IWS.

##### 1. PROCEDURES FOR COMPUTER CONTROLLERS COLD START

Cold start up for a computer controller is necessary if the computer is powered down or is not working under the Pascal operating system.

##### 1.1. Controller Cold Start Up

All of the computers except the CMM computer have the same cold start up procedure. Start up for the CMM computer is discussed in Section 1.2.

##### 1.1.1. Turn Them On

Each of the computer systems consists of a hard disk, a central processing unit, a keyboard, and a monitor. Each component of the system is connected to a power outlet which is located next to the monitor screen. To turn on a system, simply flip the red switch so that the light turns on.

##### 1.1.2. Boot Up Pascal

Upon power up, the computer system will attempt to boot up. When you hear a tone you must press ENTER, then lp to select Pascal as the working operating system. After Pascal is chosen, the computer will complete boot up and will come up in the correct directory for the most up to date version of the IWS software.

##### 1.1.3. Set The Date And Time

To set the date in the correct format, for example September 13,



1987, type 13-SEP-87 [ENTER]. ([ENTER] refers to the key labeled 'ENTER'.) To set the time for 9:36 am type 9:36 [ENTER].

### 1.2. CMM Computer Cold Start Up

Before starting the CMM computer, be sure the start up disk is in the right hand disk drive. Then, simply press the ^AC LINE button on the front right of the keyboard to turn on the power. The computer will boot up off of the diskette and will come up in the correct directory for the most up to date version of the CMM software. Enter the correct date and time and proceed with start up.

## 2. PROCEDURES FOR EQUIPMENT COLD START

This section contains specific procedures for starting up the IWS equipment from an extended cold shut down state. If these instructions fail to start the equipment, refer to Chapter VII of this document for trouble-shooting directions.

### 2.1. Cold Start For The CMM

#### 2.1.1. Turn It On

Two steps have to be taken to turn on the CMM. First, shift the Power On lever to the right. This lever should always be left turned on. Next, press the Ready/Servo On button. (See Figure 10.)

#### 2.1.2. Calibrate The PH9 Probe

The PH9 Probe has to be recalibrated only if the main power to the CMM has been off for more than 24 hours. This could occur due to a power outage or if the main power to the CMM was turned off. (Normally, the main power to the CMM is always left on. The 24 hour leeway is due to a battery backup.) If the power has not been interrupted for over 24 hours, you can skip the calibration procedure and go to Section 2.2. Otherwise, the PH9 Probe must be calibrated prior to operation. To calibrate the probe, follow these instructions.

##### 2.1.2.1. Execute The Calibration Program

At the CMM Controller computer, execute the calibration program by entering `xcordax:runcmm`. Choose 1 as the debug string from the first menu and then press enter when asked to do so. Subsequently, enter k from the second menu to enable keyboard input. It will now be possible to issue FLB commands to the CMM.



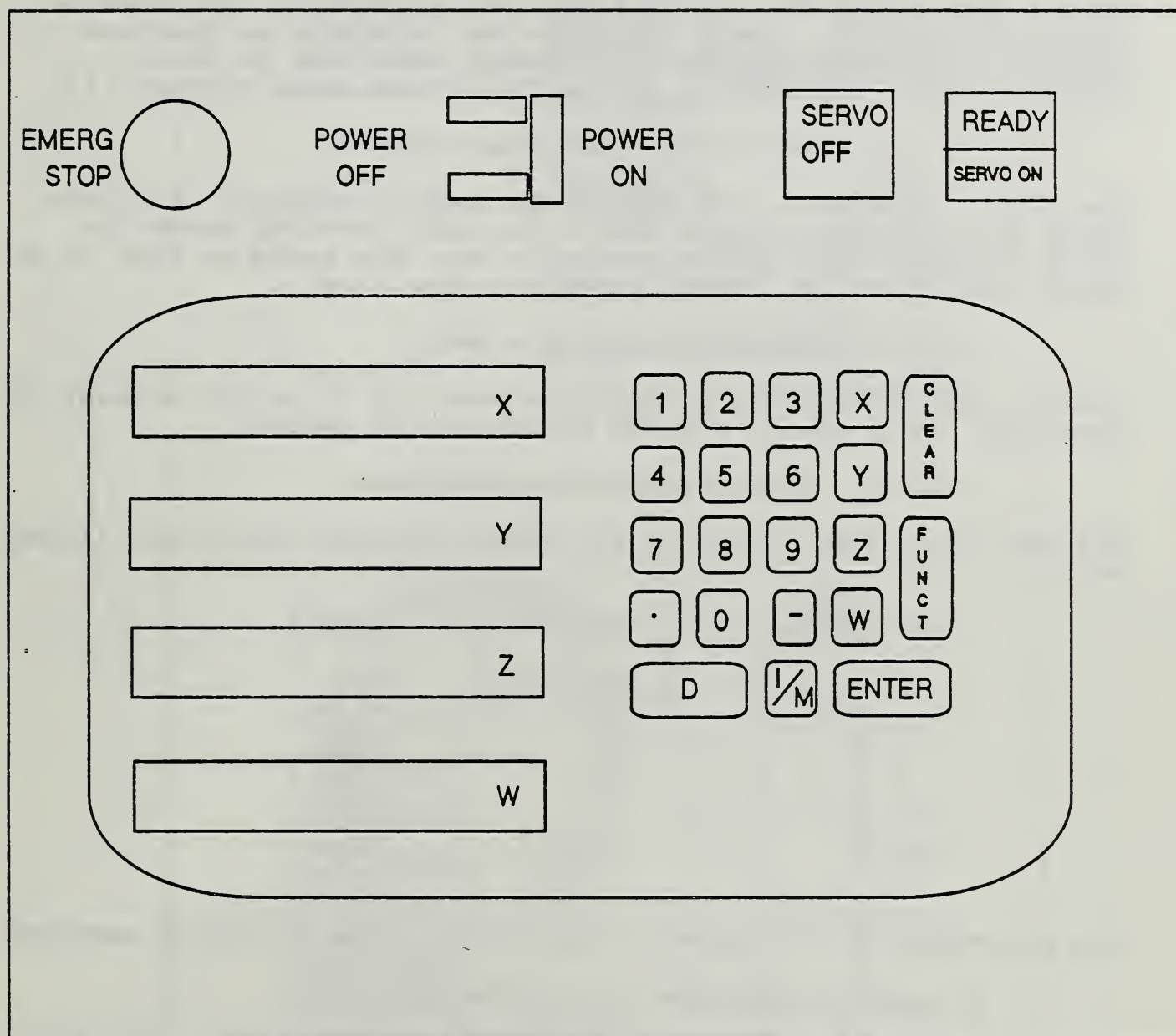


Figure 10. CMM Control Panel



#### 2.1.2.2. Activate Pendant Joysticks

If the servos are not on, turn them on by pressing the Servo On button (Figure 10). Next, activate the joysticks on the hand pendant by pressing MAN to go to manual mode, JOY to select joystick mode, and SLOW to reduce the motion speed (Figure 11).

#### 2.1.2.3. Move Probe Away From Table

The right joystick on the pendant is used to maneuver the probe north and south and up and down. The left joystick moves the table east and west. Very carefully move the probe so that it is positioned about six inches above the gage block.

#### 2.1.2.4. Switch To Absolute Mode

Switch from incremental to absolute mode (if it is not already in that mode) by pressing the ABS button on the pendant.

#### 2.1.2.5. Probe Calibration Positions

The PH9 probe must be set to the seven different positions listed below.

Probe	Axis A	Axis B
0	90	-90
1	90	-110
2	90	-180
3	70	-90
4	100	-120
5	0	-90
6	105	-70

The procedure to set these is described in the following sections.

#### 2.1.2.6. Calibrate Zero Probe Position

Push Probe Axis A button on the pendant and enter 90. Then push Probe Axis B button and enter -90. To enter a minus number, first enter the number and then press the +/- button. The probe will be oriented vertically and pointing downward. Using the pendant joysticks, carefully move the probe so that it is positioned over the center of the steel ball (located at the southeast corner of the table, and called the calibration sphere) and about six inches above it. Make sure the speed is set to slow before moving the probe.



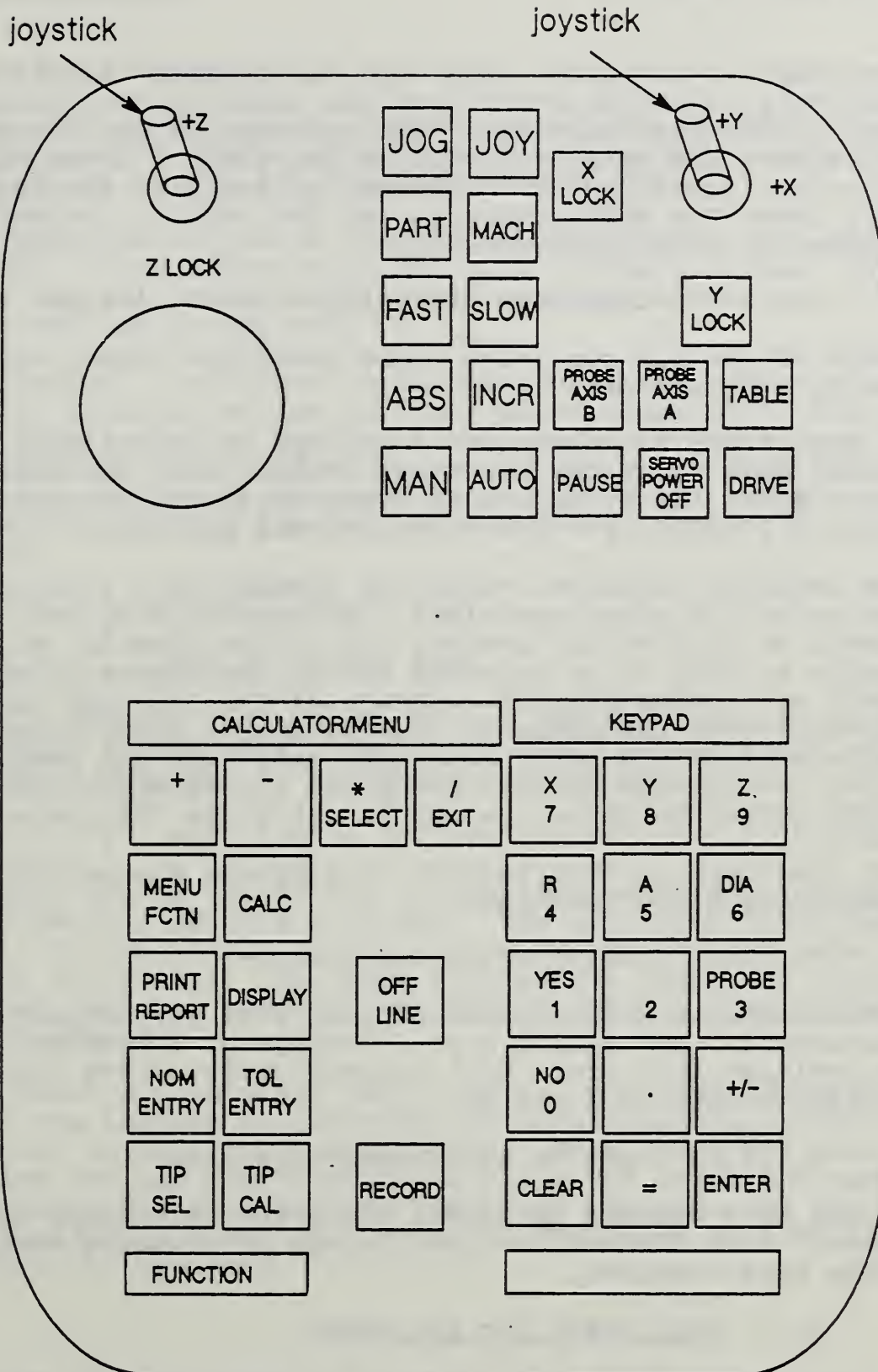


Figure 11. CMM Pendant



At the computer keyboard, enter the FLB command `calfxtr sp,1.5,p6`. Subsequently, enter `ah` and follow the instructions given on the monitor of the hand pendant or the computer screen. You will be asked to move the probe to specific positions. After each positioning, press the RECORD button to register the point. Lastly, press the AUTO button to let the machine automatically calibrate the zero probe position.

#### 2.1.2.7. Calibrate Remaining Probe Positions

For each of the six remaining probe positions comply with the following instructions.

Press **MAN**, **SLOW**, and then **JOY** to go back to manual mode. Carefully move the probe about six inches above the calibration sphere. Enter the A and B axis probe orientation values specified in Section 2.1.2.5. for the current probe position.

At the computer keyboard, enter the command at 1 (through at 6 depending on the probe position). As specified by the instructions on the hand pendant and on the computer screen, move the probe so that it is pointing toward the center of the ball and is about six inches from the surface of the ball and then push the RECORD button on the pendant. Subsequently, move the probe 0.25 inches away from the ball, but again make sure the probe is still pointing towards the center, and press the RECORD button. Press the AUTO button to allow the CMM to calibrate the probe position.

Repeat the steps in this section to complete the calibration for the remaining probe positions.

#### 2.1.2.8. Verify Probe Calibration

Move the probe to a safe position away from any objects. Verify the calibration by issuing a `gt 0` through `gt 6` command. For each probe position, the probe will automatically orient itself as specified in Section 2.1.2.5.

#### 2.1.2.9. Move To Zero Probe Orientation

Issue the `gt 0` command to orient the probe vertically and pointing downward. Stop the calibration program by pressing the HP Shift and Stop keys together.

### 2.2. Cold Start For The Robot

It is recommended that the operator be familiar with the Robot operating procedures before attempting to handle the Robot.



### 2.2.1. Turn It On

The power must be turned on at the wall circuit switch. It is not usually turned off there. Then turn on the switch on the box on the east column of the Robot gantry (Figure 12).

Push the power on button on the control box on the west column (Figure 13). This button will not work if the red power off button is not released. To release the power off button, turn it clockwise and let it pop out.

Push the battery low button on the control panel. This closes a relay which would otherwise hold the power supplied to the control boards a little too low and cause extraneous move errors. Wait about three minutes for the system to load. When the display on the teach pendant is the same as in Figure 14, the American Robot Operating System has been loaded and the Robot is operational.

### 2.2.2. Calibrate Robot Arm

#### 2.2.2.1. Switch to Arm Mode

Press MVM 0 [ENTER] and then Machine 0 [ENTER] from the pendant to put the Robot in arm mode. The Machine key is the green shift of the MVM key. This key is not explicitly labelled.

#### 2.2.2.2. Move Arm To Calibration Position If Necessary

If the Robot arm is not in the calibration position, you must use the teach pendant to move it there. The arm calibration position is roughly in the middle of the gantry track with the Robot arm completely horizontal. For more information about the correct arm calibration position, consult the Merlin Robot System Operators and User Guide [3].

With the Robot arm pointing east, set the position/orientation switch on the pendant to position and straighten the elbow using the joystick so that it is horizontal. Then, flip the switch to orientation and use the joystick to align the wrist and hand joints so that the blue markers match up. Lastly, set the switch back to position and turn the waist of the Robot so that it is in the calibration position.



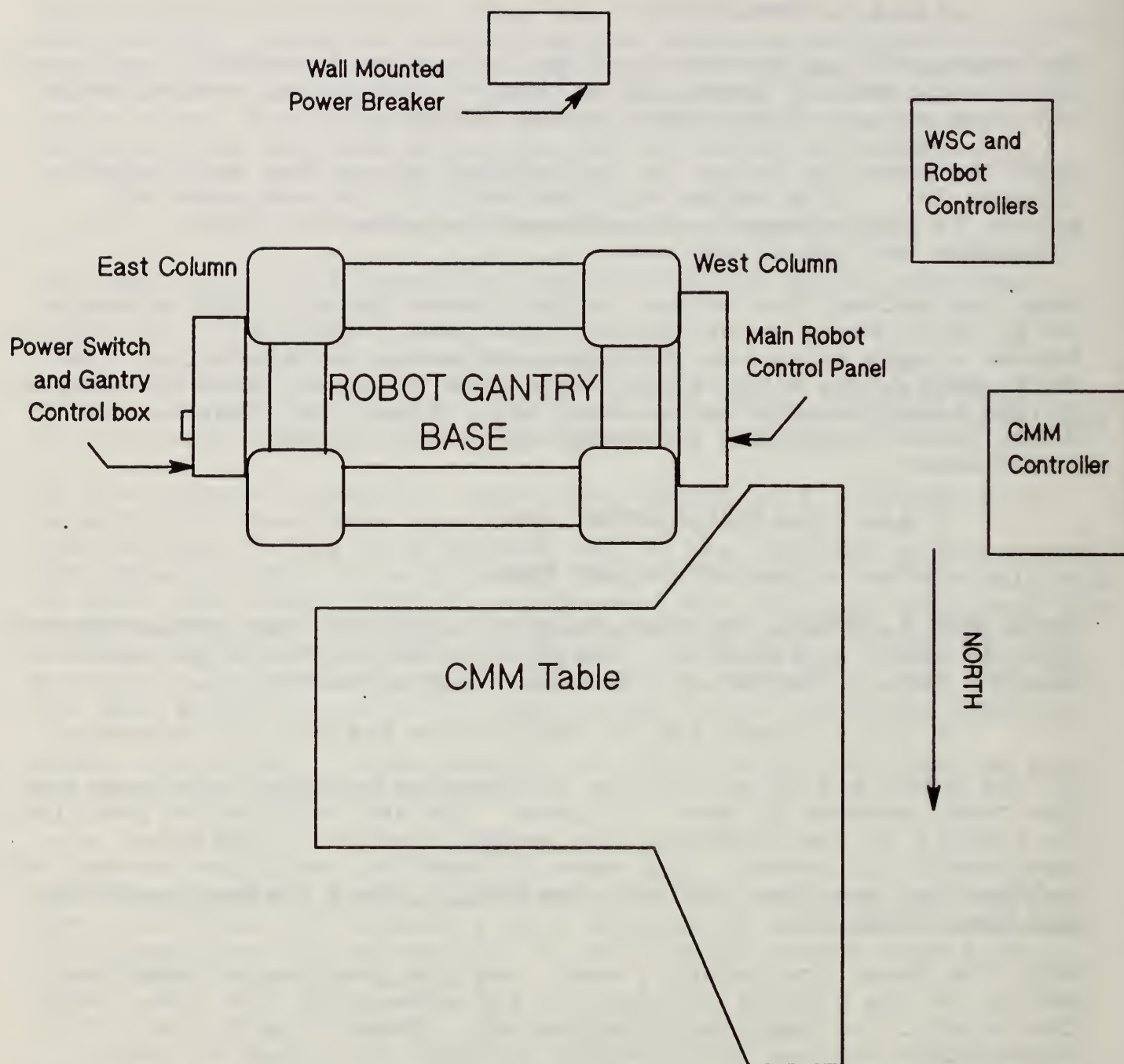


Figure 12. Robot Control Locations.



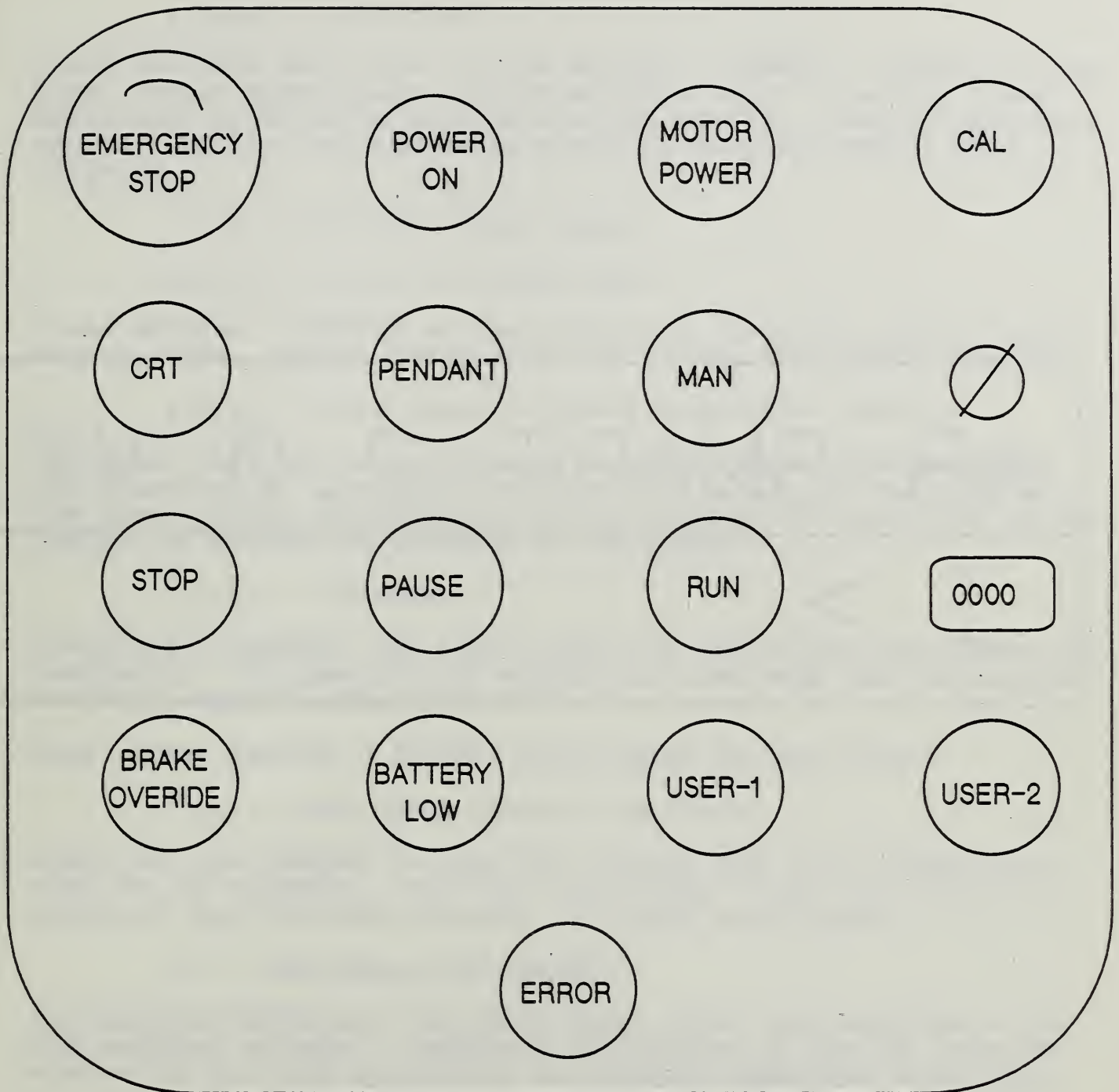


Figure 13. Robot Control Panel



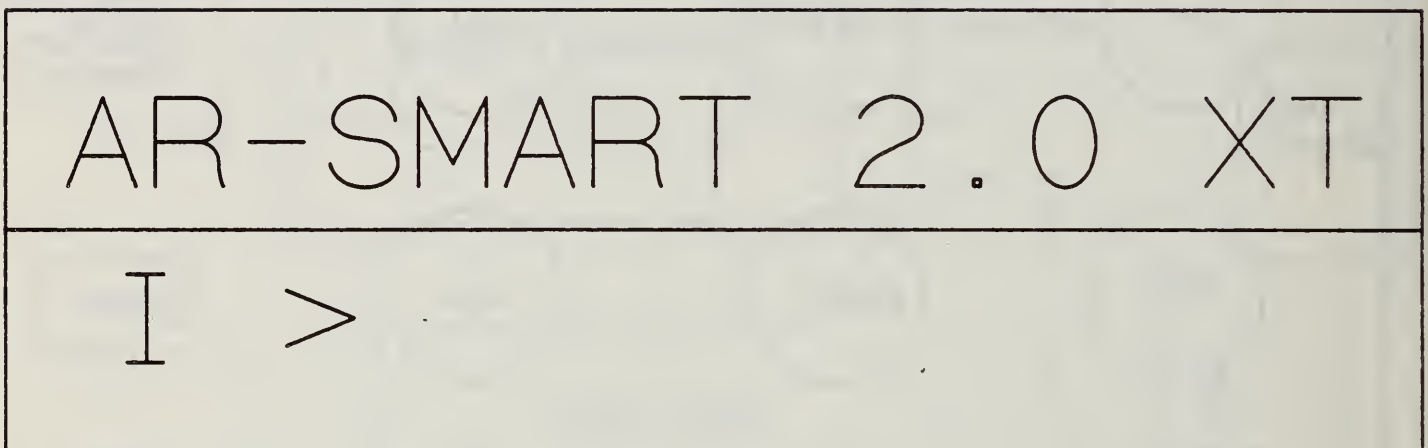


Figure 14. Robot Display After  
System Software Loaded



### 2.2.2.3. Calibrate

Press CLB (red shift CLB) on the pendant. Answer 1 [ENTER] to the first prompt which means a power on calibration. Lastly, Press ENTER when prompted to confirm the calibration. The arm will move around a little, and the pendant will display CAL PROC 1 when finished.

### 2.2.3. Calibrate Robot Track

#### 2.2.3.1. Switch To Track Mode

Press Machine 1 [ENTER] on the pendant to choose the gantry track machine mode. Again, the Machine key is the Green shift MVM key.

#### 2.2.3.2. Move Robot To Track Calibration Position

Using the joystick on the pendant, move the gantry (towards the IWS entrance) to a position about an inch south (to the back of the room) of the calibration position (marked by a red line on the gantry) by moving the joystick to the right.

#### 2.2.3.3. Calibrate

Press CLB 1 [ENTER], and lastly push the yes button when asked Cal Machine 1?. The gantry will search and then stop when calibrated and will respond with CAL PROC 1.

Next, press Machine 0 [ENTER] which makes the arm active.

### 2.2.4. Load Robot Program (am\_robot)

Press LPG 400 [ENTER] to load the program that will communicate with the HP computer. Wait for the prompt: I>lpg 400 which will indicate that the Robot program is loaded into memory.

## 2.3. Cold Start For The SRI

The Surface Roughness Instrument power lines are connected to the SRI computer outlets. Therefore, by turning on the SRI computer system you are also activating the Surface Roughness Instrument.

## 2.4. Cold Start For The ADI

The Automatic Dial Indicator is also connected to the SRI computer outlets; therefore, same as above, the ADI is started by turning on the SRI system. The display on the ADI should be on and should be all zeroes. If it is not on, press the button on the ADI labeled 0 (see Figure 4).



## 2.5. Safety Fence

The Safety Fence console consists of a fence power on/off switch, a fence reset button, an audio on/off switch, and various light indicators. (See Figure 6.) The instructions for operating these are presented in the following sections.

### 2.5.1. Experimental Operation

During experimental operation, the safety fence is generally left turned off. However, if you decide to keep it off, be very careful of safety.

### 2.5.2. Unattended Operation

Before turning on the safety fence, first press the reset button until the fence light indicator stops flashing. Then, flip the fence switch to on. If you want to turn on the alarm in the event that the fence is triggered, flip the audio switch to on.

## 3. PROCEDURES FOR EQUIPMENT WARM START

Warm start is necessary to synchronize the IWS equipment with the IWS Controllers. This is required when the IWS is initially started up, or when it is restarted after an error has crashed the system.

### 3.1. Warm Start For The CMM

Prior to warm starting the CMM, the CMM probe tip must be positioned at the CMM Origin. This position is defined by the top center of a gage block which is located at the southwest corner of the CMM table. This gage block has a hemispherical hole cut in its top, so that the center of the probe tip may be positioned at the correct location. (See Figure 15.)

To activate the joysticks, press the following pendant buttons: MAN, JOY, and SLOW. The Probe can now be moved by manipulating the two joysticks on the pendant. Very carefully position the red probe tip to the CMM Origin.



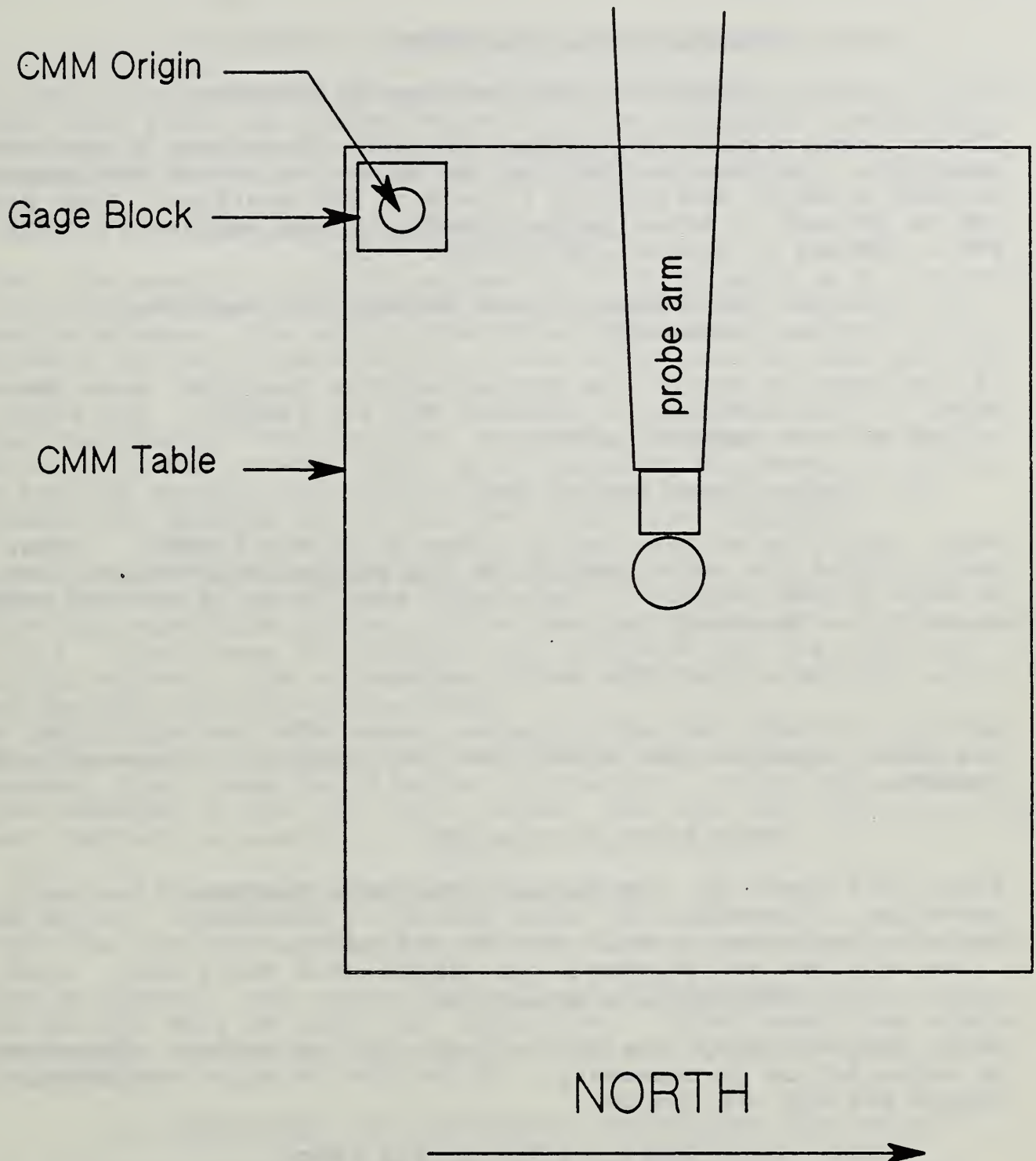


Figure 15. CMM Origin



### 3.2. Warm Start For The Robot

#### 3.2.1. Stop The Robot Program If Necessary

If the Robot program is running, you must first stop the program execution. Do this by flipping the rocker switch on the pendant to STOP briefly, and putting it back to RUN position. Then press IMM to go back to manual mode. Lastly, press Machine 0 [ENTER] MVM 0 [ENTER] to enable arm movement mode.

#### 3.2.2. Move Robot To Arm Calibration Position If Necessary

If the Robot is not at the arm calibration position, move the Robot to that position by pressing MOV 199 [ENTER]. The Robot will move to a vertical position.

#### 3.2.3. Clear Serial Port

Next, clear the serial port by pressing IN 801 [ENTER]. Then, again toggle the rocker switch on the pendant to STOP and then put it back to RUN position. You should see the sp rd aborted message flashing on the teach pendant.

#### 3.2.4. Start The Robot Program

Lastly, to start the Robot program, press RUN (red shift RUN) on the teach pendant. You should see the running ... message on the pendant.

### 3.3. Warm Start For The SRI

After Cold Start Up, the Surface Roughness Instrument is ready for operation. Therefore, no extra set up is necessary. If the IWS is to be restarted, toggle the SRI off and on.

### 3.4. Warm Start For The ADI

After Cold Start Up, the ADI is ready for operation. Therefore, no extra set up is necessary. If the IWS is to be restarted, toggle the ADI off and on.

### 3.5. Warm Start For The Safety Fence

The Safety Fence can be turned on at any time; however, the fence reset button must be pressed before the fence is activated.



#### 4. PROCEDURES FOR EQUIPMENT CONTROLLERS WARM START

To begin operations, a program called the execution control system (ECS) must first be started on each of the equipment controllers. Note that all entries to the HP computers must be entered exactly as specified here. (I.e. 'a' is not the same as 'A'.)

##### 4.1. Starting The CMM Controller

Start the execution control system by first pressing s to "stream" a file. Then press ECS [ENTER] when prompted for the file you want to stream. The appropriate files will be loaded into memory and then the servo power will be deactivated and the CMM will be reset.

When the message Press Execute to Continue appears on the CMM monitor, finish the CMM start up by pressing the servo on button on the CMM console, the AUTO button on the hand pendant, and finally the EXECUTE key on the CMM Controller computer.

##### 4.2. Starting The SRI Controller

Start the execution control system by first pressing s to "stream" a file. Then press ECS [ENTER] when prompted for the file you want to stream. The appropriate files will be loaded into memory and the SRI and ADI will be reset.

When the controller displays the Press M button prompt, wait 5 seconds, then press the M button on the ADI. If the SRI screen shows WORKING in the top right corner, then the SRI Controller has been started successfully.

##### 4.3. Starting The Robot Controller

Start the execution control system by first pressing s to "stream" a file. Then press ECS [ENTER] when prompted for the file you want to stream. The appropriate files will be loaded into memory and the IRC will be ready for operations. After about one minute, the message 0.00000 will be displayed on the teach pendant. (See Figure 16).

#### 5. PROCEDURES FOR WORKSTATION CONTROLLER WARM START

The Workstation Controller can be operated in integrated mode, where commands are received from the AMRF Cell Controller, or in stand-alone mode, where commands are received from the user interface. Be sure your keyboard entries are exactly what is specified here. (Remember, 'a' is not the same as 'A'.)



Various Workstation Controller operation options have been set by default. To change the Workstation Controller operating options prior to operation, edit the file `wsc_31:debug`. To change the Data Server operating options, edit the file `ds_31:debug`. The editing must be done before warm starting the Workstation Controller. Look at Figure 17 for the list and effects of the operating options.

### 5.1. Integrated (Connected To Cell)

Start the execution control system by first pressing `s` to "stream" a file. Then press `ECS` [ENTER] when prompted for the file you want to stream. The Workstation Controller will now be activated and the operation will be run by the Cell Controller.

### 5.2. Stand Alone (User Interface)

#### 5.2.1. Starting The Execution Control System

Start the execution control system by first pressing `s` to "stream" a file. Then press `ECS2` [ENTER] when prompted for the file you want to stream. The appropriate files will be loaded into memory and the system will attempt to set up the Workstation Local Network.

Wait for the message network established to be displayed before proceeding. When you see the message, press the ENTER key. If the message does not appear after an inordinate amount of time, refer to Chapter VII on network set up errors.

You will then be shown the list of permissible Workstation Controller commands. Press `1` [ENTER] to change the Workstation Controller operating options or `2` [ENTER] to change the Data Server operating options. These options can be set at any time with no effect to the operation of the controller.

Before inspection work orders can be issued, the workstation has to be set up.



sPrd aborted

I > 0.000000

Figure 16. Robot Display When  
A Program is Running



Option	Effect
d	Turn on the Workstation status display
e	Turn on Error Message Display in case of error
f	Use SCRIPT1 by default for Order Action retrieval
l	Inspect a Tray Continuously
m	Write Operation History to File

Figure 17. WSC Operating Options



### 5.2.2. Workstation Synchronization

You must first synchronize the Workstation Controller with the other equipment controllers; therefore, press 3 [ENTER] to issue the Synchronize command. It takes about 15 seconds to synchronize the Inspection Workstation controllers.

### 5.2.3. Workstation Warm Start Up

You can now either warm start up to complete set up or cold shut down to turn off the system. You have to send a Warm Start up command before you can issue work orders. Press 3 [ENTER] to issue a Warm Start up command. Refer to Chapter VI, Section 4.1. to perform cold shut down of the Inspection Workstation.

It takes about one minute for the Workstation Controller to warm start the system.







## V. OPERATING INSTRUCTIONS IN READY STATE

Once the IWS is started up, it is in an operational state called the Ready State. From this state the IWS can receive trays of parts, inspect those parts, and ship them off. The IWS remains in this state until a shut down is ordered, or an error crashes the system.

Without the benefit of a vision system, it becomes the duty of the operator to inspect the position of each part in the tray container and to reposition the parts if necessary. This is required for both integrated and stand alone operations. If any part is too far off its correct position, it can crash the entire workstation.

There are three trays of parts that are currently being used in the IWS for testing and demonstrations. These trays are designated 510, 520, and 530. The locations of parts on these trays are shown in Figures 18 to 20.

### 1. INTEGRATED MODE

Under Cell control, there is nothing further required for the operator unless there is an error. In the event of an error, refer to Chapter VII for error recovery instructions.

### 2. STAND ALONE

#### 2.1. Equipment Controllers

Unless there is an error, the only interaction allowed by the operator is through the Workstation Controller.

#### 2.2. Operating Instructions For The WSC

In Ready State, you can either issue work order commands to perform the inspection process or a warm shut down command to shut down the Inspection Workstation.

##### 2.2.1. Work Orders

To create, edit, manage, and dispatch work orders press 3 [ENTER] at the main Workstation Controller menu. This will put you in the work order menu.

A work order consists of a fixed order action data section and a variable order parameter data section. The fixed section - specifies the work order identification number, work element,



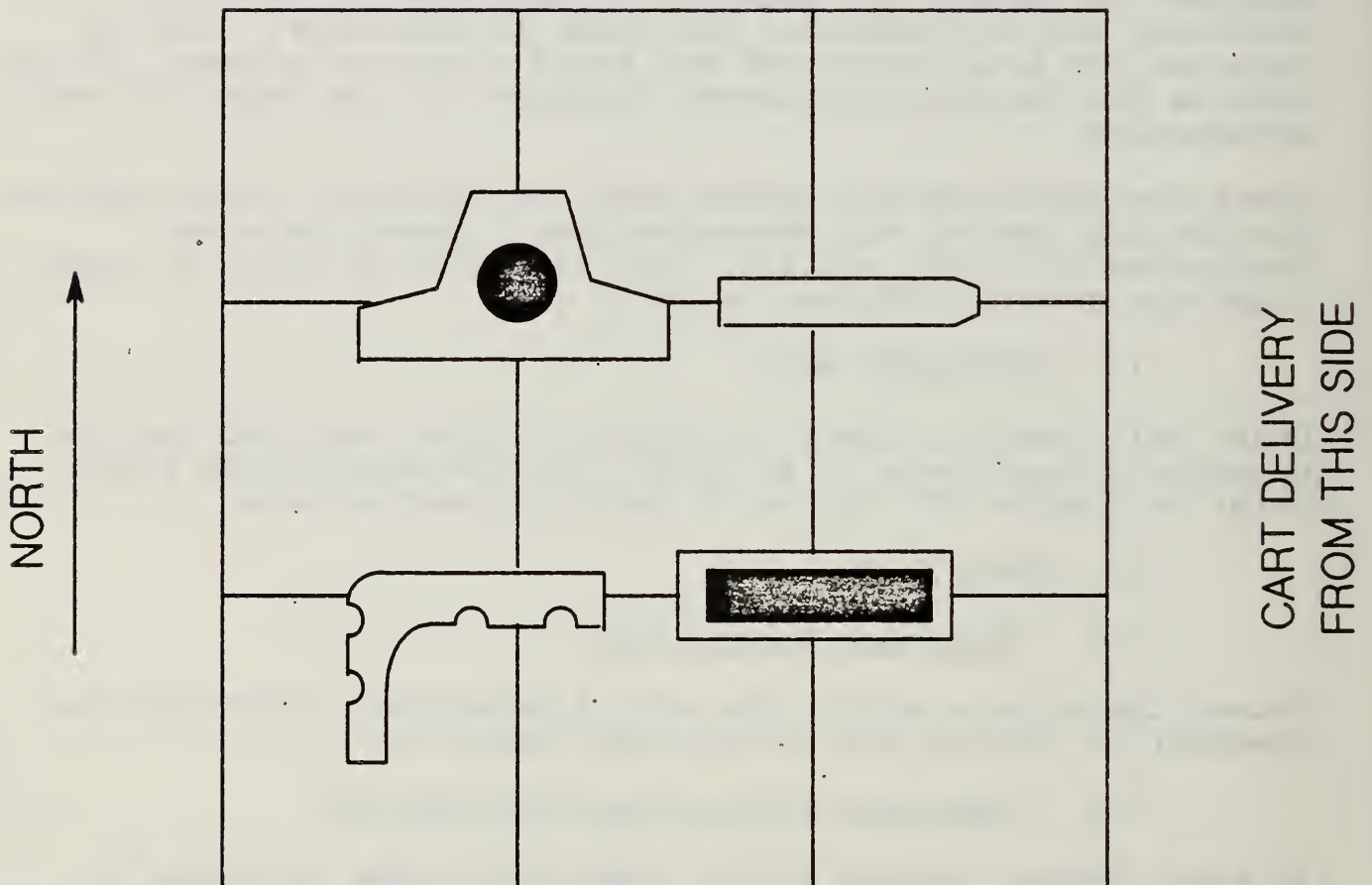


Figure 18. Tray 510



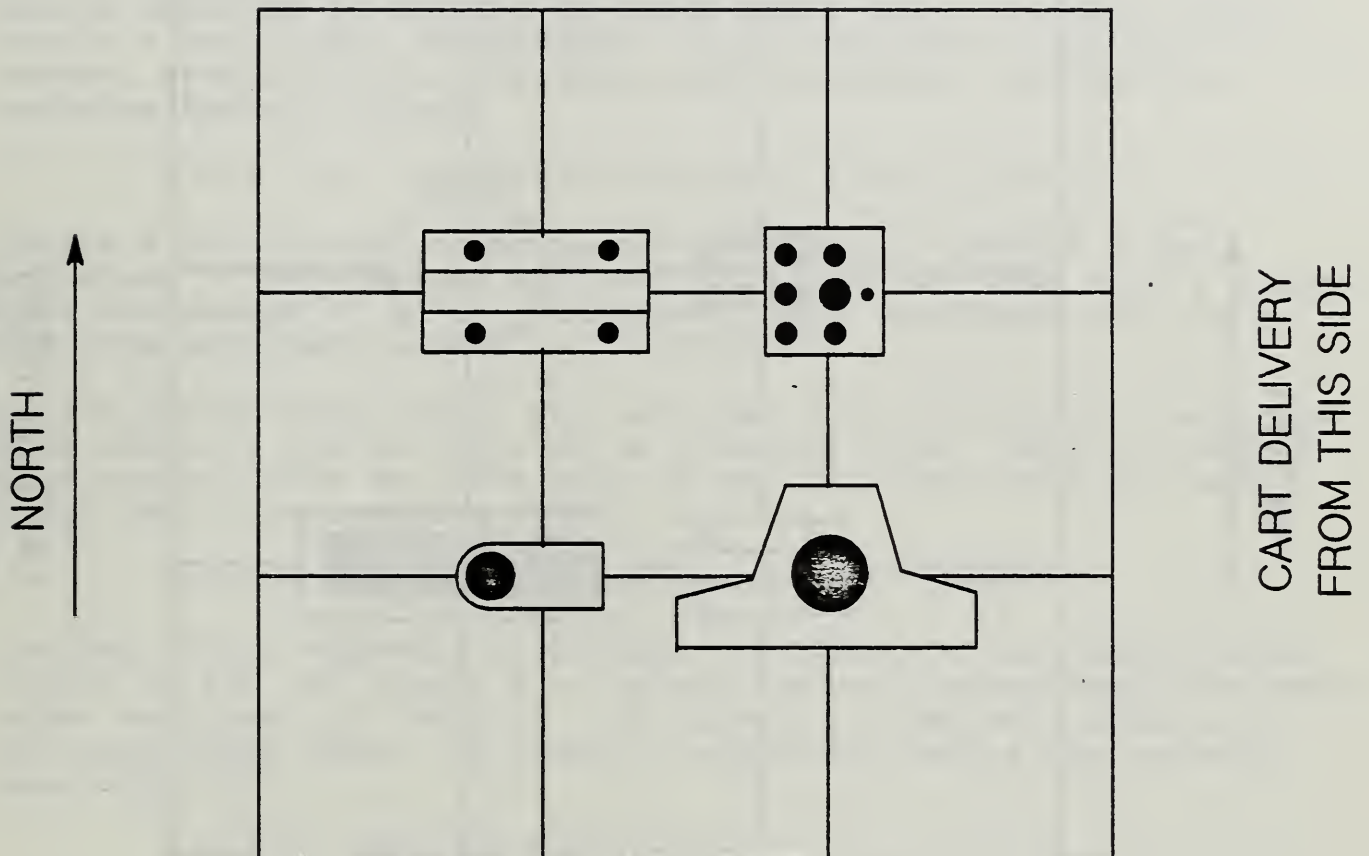


Figure 19. Tray 520



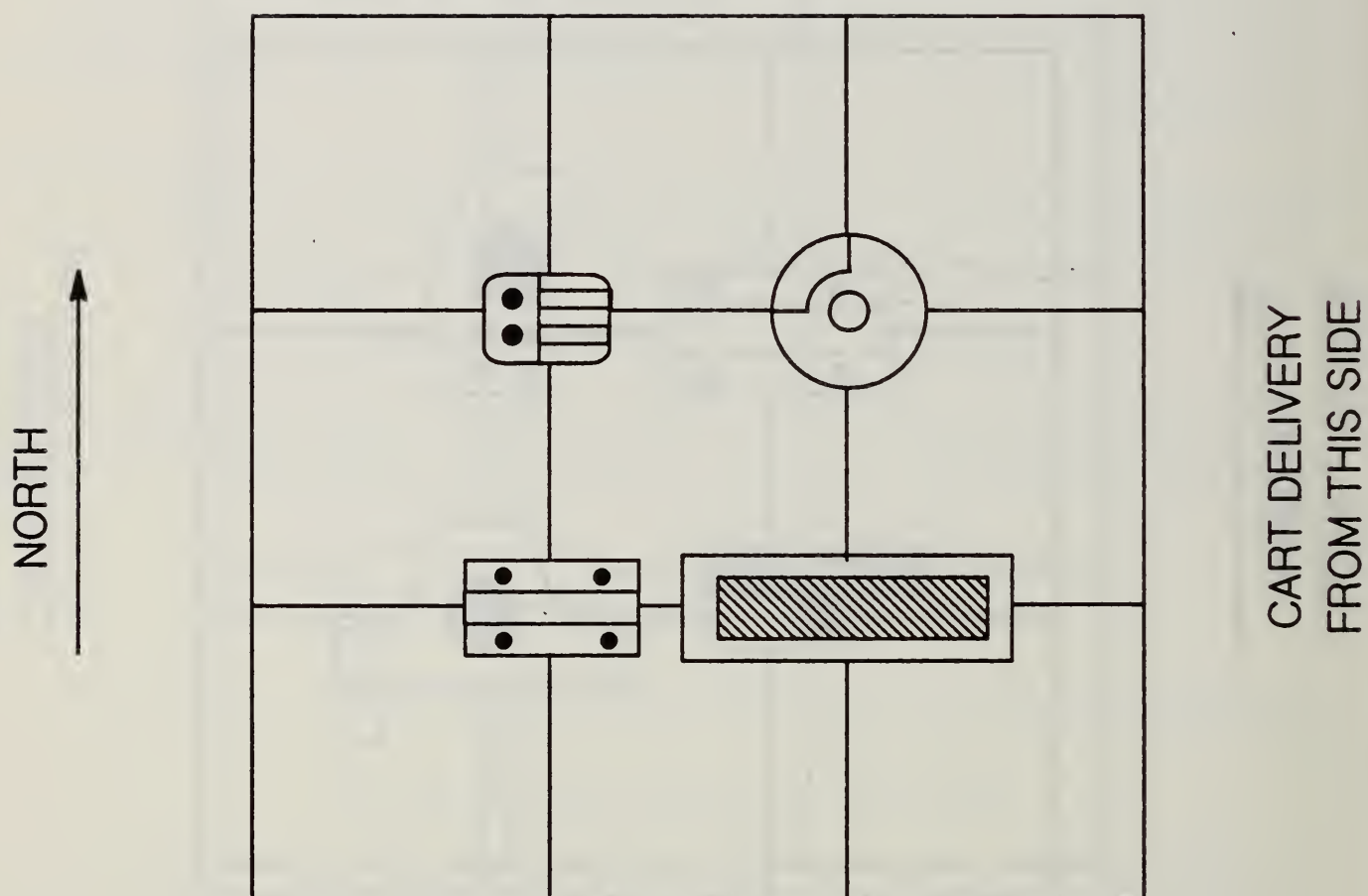


Figure 20. Tray 530



update number, and order action. The variable section consists of data pertinent to the particular work order.

The AMRF architecture specification stipulates that more than one work order can be sent per cell command. This section is written as if you can enter multiple work orders. However, the current implementation will not allow you to do that--the WSC will only accept one work order per command.

#### 2.2.1.1. Creating Work Orders

Before entering or editing the work order data, you must first create a work order "worksheet". This worksheet, displayed on the screen, specifies the work order data necessary and initially contains default values.

##### 2.2.1.1.1. Automatic Creation Of Work Orders

Option 9 of the work order menu automatically creates a new worksheet if none exists and then retrieves the data from a script file and enters it in the worksheet. If a worksheet does exist, then the worksheet's data is overwritten.

If you choose this option you can then skip directly to issue the work order if you do not wish to edit the data. Notice, however, that you can edit the data even if you have retrieved the work order data from a script file.

##### 2.2.1.1.2. Manual Creation Of Work Orders

You can either append a work order worksheet to the list of work orders or you can insert a worksheet before another specified work order worksheet in the list. To append a worksheet, enter 2 at the work order menu. To insert a worksheet before the current one, enter 3.

#### 2.2.1.2. Editing Work Orders

##### 2.2.1.2.1. Editing Work Order Action Data

To edit the work order action data, enter 7 at the work order menu. Subsequently, enter the appropriate number for the work order action datum you wish to edit and respond accordingly. Enter 1 to get out of the work order action data menu.

##### 2.2.1.2.2. Editing Work Order Parameter Data

To edit the work order parameter data, enter 8 at the work order menu. As with the work order, you must also create a parameter



worksheet before you can enter the data. Enter 2 or 3 to either append or insert a parameter data worksheet.

After doing so, you can proceed to enter the data by selecting option 7 of the work order parameter data menu. Enter the appropriate number for the work order parameter datum you wish to edit and respond accordingly. Enter 1 to exit the edit parameter data menu.

You can create new work order parameters by entering either 2 or 3, or you can enter 1 if you are finished editing parameter data and wish to leave the order parameter data menu.

#### 2.2.1.3. Moving To Other Work Orders

You can either go to the next or previous work order in the list if it exists. To go to the next work order, enter 4. To go to the previous work order, enter 5.

#### 2.2.1.4. Deleting A Work Order

Enter 6 at the work order menu to delete the current work order. The work order after the one to be deleted will become the new current work order.

#### 2.2.1.5. Issuing Work Orders

Finally, after you have created and edited the work orders, you can either issue the work orders or you can quit without issuing the command. To issue the work orders enter 10 from the work order menu. If on the other hand you do not want to issue the work order, enter 1 instead.

Note that the work orders that were created will remain in the system until they are deleted or the execution control system is terminated. Every time the work order menu is entered, the first work order in the list will be displayed on the screen.

#### 2.2.2. Warm Shut Down

Refer to Chapter VI, Section 2.1. for workstation warm shut down instructions.

### 3. RESTARTING THE IWS

#### 3.1. Restart Equipment

Refer to Chapter IV, Section 3, to restart the IWS equipment.



### 3.2. Restart Controllers

Refer to Chapter IV, Section 4, to restart the IWS equipment controllers and to Chapter IV, Section 5, to restart the Workstation Controller.







## VI. SHUTTING DOWN THE WORKSTATION

### 1. SHUT DOWN STATES

As defined in the AMRF architecture specification, there are two types of shut down: warm shut down and cold shut down. Two other states were added at the Inspection Workstation to account for more varied circumstances. Therefore, there are now four levels of shut down defined: warm shut down, extended warm shut down, cold shut down, and extended cold shut down. The two new states pertain only to the workstation equipment.

#### 1.1. Warm Shut Down

Warm shut down is performed when the workstation is in the ready state and the operator wants to discontinue operations but leave the workstation enabled.

#### 1.2. Extended Warm Shut Down

Extended warm shut down is executed after warm shut down and is meant to disable some of the workstation equipment if operations are suspended temporarily.

#### 1.3. Cold Shut Down

Cold shut down is performed when the workstation is in the warm shut down state and the operator wants to terminate the execution control system on the computer controllers and disable, but not power down, all of the workstation equipment.

#### 1.4. Extended Cold Shut Down

Extended cold shut down is executed after cold shut down and is used to power down all of the workstation controllers and equipment when operations are halted indefinitely.

### 2. PROCEDURES FOR WARM SHUT DOWN

#### 2.1. Workstation Controller

To issue a warm shut down command, press 4 [ENTER] from the main Workstation Controller menu. The warm shut down command causes the Workstation Controller to transition from a ready state to a warm shut down state. However, before warm shut down, the Workstation Controller will complete all of the pending work orders.



After warm shut down, the operator can either get back to ready state by warm starting the workstation using the instructions of Chapter IV, Section 5.2.3. or cold shut down the system by referring to Section 4.1. of this chapter.

## 2.2. Equipment Controllers

The warm shut down commands to the equipment controllers are issued automatically from the Workstation Controller. There are therefore no procedures for equipment controller warm shut down.

## 3. PROCEDURES FOR EXTENDED WARM SHUT DOWN

### 3.1. Computer Controllers

To protect the computer's monitor screens, turn down the brightness intensity of the monitors. However, leave the execution control system running on the computer controllers.

### 3.2. Coordinate Measuring Machine

To warm shut down the CMM for an extended period of time, turn off the servo motors by pressing the Ready/Servo On button on the CMM console.

## 4. PROCEDURES FOR COLD SHUT DOWN

### 4.1. Workstation Controller

To cold shut down the IWS, press 4 [ENTER] at the main Workstation Controller menu. Cold shut down takes about one minute.

### 4.2. Equipment Controllers

The cold shut down commands to the equipment controllers are issued from the Workstation Controller.

### 4.3. Stop The Execution Control System

After the workstation has been shut down, press the Shift and Stop (printed in blue) keys together to stop the execution control system. Then press the I key to initialize the computer.

To restart the equipment controllers, use the procedures of Chapter IV, Section 4. To restart the Workstation Controller, use the procedures of Chapter IV, Section 5.



#### 4.4. Robot

##### 4.4.1. Stop The Robot Program

Stop the Robot program by flipping the switch on the pendant to STOP briefly, and putting it back to RUN position. Then enter IMM to go back to manual mode.

##### 4.4.2. Move Robot To Arm Calibration Position

Press Machine 0 [ENTER] and then MVM 0 [ENTER] to make the Robot arm movement active. Press MOV 199 [ENTER] to move the arm into calibration position.

##### 4.4.3. Move Robot To Track Calibration Position

Press Machine 1 [ENTER] to activate the Robot track movement. Press MOV 950 [ENTER] to move the gantry into calibration position.

#### 4.5. CMM

If the CMM Controller was shut down normally, the probe tip will be properly positioned at the CMM Origin, and nothing further need be done.

Otherwise, press MAN, JOY, and SLOW on the hand pendant to activate the joysticks. Then use the joysticks to position the probe back in the CMM Origin.

### 5. PROCEDURES FOR EXTENDED COLD SHUT DOWN

#### 5.1. Computer Controllers

All of the computer system components are connected to the main power outlet located near the monitor screen. Turn off each of the computer systems by flipping the outlet's red switch so that the light goes off.

#### 5.2. Robot

Power down the Robot by turning off the switch on the box on the east column of the Robot gantry. Then push the red power off button on the control box on the west column so that it locks on the catch.



5.3. CMM

Turn off the CMM by pressing the Servo Off button. Leave the power on lever switched to the right.

5.4. SRI

The SRI power cables are connected to the SRI Controller computer system; therefore, in turning off the SRI computer you also turn off the SRI.

5.5. ADI

The ADI is also connected to the SRI Controller computer system. The ADI is powered down by turning off the SRI Controller.



## VII. ERROR HANDLING

Currently, most errors that happen at the IWS are nonrecoverable. Therefore, if an error does occur, the workstation usually has to be restarted from a Warm Start.

### 1. TYPES OF ERRORS

Equipment errors and Controller errors are the two types of errors that take place at the IWS. Equipment errors arise from faults in the inspection operation. Controller errors occur when the execution control system on any of the controllers locks up. Discussion on specific errors follows in the succeeding sections.

### 2. CMM ERRORS

#### 2.1. Missed Part

If the CMM probe tip does not contact the part within a travel specified by data, the CMM reports an error and kicks over into manual operation. The main reasons for this error are: the Robot placed the part on the CMM too far out of position for the CMM to find it; the wrong part was put on the CMM; or the data specifying the part conflicts with the actual part being inspected. The latter could occur, for example, if a hole was machined where an inspection point was specified. This error is nonrecoverable. The IWS must be restarted.

#### 2.2. Unexpected Touch

A CMM error also occurs if the probe tip contacts the part (or any object) when it is attempting to simply move to a new location. The same reasons causing the missed part error could cause this error. Again the CMM is kicked into manual operation, and the IWS must be restarted.

#### 2.3. Program Hangs

There are a number of reasons why the CMM Controller will become 'locked up' and not be able to continue its operations. This could occur if the communication between the HP computer and the CMM becomes garbled. Another reason is that the program reaches an illegal state from which it cannot recover.

Whatever the circumstance that caused the lock up, the result and corrective measures required are the same. The controller must be stopped (by pressing the shift and stop keys simultaneously on the HP keyboard) and the IWS must be restarted.



### 3. SRI ERRORS

#### 3.1. SRI Display Changes To F's

If the SRI Display changes to a series of F's, this indicates that an SRI error has occurred. There is no way to recover from this error; therefore, the IWS must be restarted.

It is possible that this error indicates a malfunction with the SRI, which must be repaired before the SRI will operate.

#### 3.2. ADI Display Goes Off

If this happens, the ADI will not return a reading to the SRI Controller, and the controller will stop operations. The power on the ADI should be turned off and on again, and the IWS must be restarted.

#### 3.3. Program Hangs

It is possible for the program to lock up for the same reasons as described for the CMM (Section 2.3 above).

### 4. ROBOT ERRORS

#### 4.1. Move Error

A move error is detected when the Robot no longer seems to be moving and move error is displayed on the hand pendant. It is possible to recover from a move error which occurs during execution. On the teach pendant, enter IMM to get out of program mode. Issue GTS 19., including the decimal point, to begin execution at step 19 of the program. Enter PGM to get back into program mode. Lastly, enter RUN to start the program. The Robot will continue with the last command issued to it.

#### 4.2. Program Hangs

It is possible for the program to lock up for the same reasons as described for the CMM (Section 2.3 above).

### 5. WSC ERRORS

#### 5.1. Process Plan Parsing Error

After the Workstation Controller retrieves the Inspection Process Plan from the IMDAS, it parses it into a local data structure. If an error occurs while parsing the process plan, the Workstation Controller will shut down and the workstation must be restarted.



## 5.2. Equipment Controllers Indicate Error

If the Workstation Controller detects an error from one of the equipment controllers, the workstation will shut down and must be restarted.

## 6. NETWORK ERRORS

### 6.1. Network Set Up Error

If an error occurs while the communication network is being established, the workstation must be restarted. If the error persists, make note of the error message which appears on the monitor of the computer signalling the error and report it to one of the workstation system staff.

### 6.2. During Operations

If an error occurs after the network has been established and is running, a network error message will be printed on the screen. This should be reported to the workstation system staff.

## 7. DATA SERVER ERRORS

Data Server errors themselves do not cause the system to shut down. The response to a data server error depends on the module making use of it.

### 7.1. Data Files Not Found

If the a request is made to the Data Server which necessitates the access of a local data file and that file does not exist, the Data Server will return a request status of error. The Data Server does not initiate shut down.

### 7.2. AMRF Data System Indicates Error

If the AMRF Data System returns an error to a transaction request, the Data Server will simply pass along the error message.







## VIII. DATA PREPARATION

Data preparation is beyond the scope of this manual. In general, the operator will not create new data or modify existing data. This chapter is provided to give a general understanding of the data required and how it is provided.

Each controller is data driven. This means that the control program that performs the controller functions is fixed, and that data is provided to allow each controller to perform its specific tasks. For example, the CMM Controller uses data to inspect a particular part with a particular inspection plan. To inspect a different part, different data is provided.

Eventually, all data that each controller needs will be retrieved from the IMDAS. (Some data will be provided as parameters of Cell commands.) After the data is retrieved, it has to be translated to the format required by the controller itself.

Currently, the only data retrieved from the IMDAS is the tray contents report, which specifies which parts are in the tray to be inspected and where they are located in the tray. All other data resides in data files that are stored in the hard disks on each controller.

### 1. CREATING AND/OR EDITING DATA FILES

#### 1.1. Who Should Do It

Creating and editing data files should only be done by someone with computer experience. Additionally, that person requires a thorough knowledge of the IWS--more so than is presented in this manual.

#### 1.2. The Editor

Editing IWS data files can be done with any editor that can create ASCII data files. The user should consult the manual that is provided with the particular editor used for exact instructions on using it. It is assumed that anyone using an editor to create data files has experience with using one.

Eventually, these files will not be created by a standard editor. Instead, they will be created automatically by an off-line programming system that will allow an operator with little (or no) computer experience as well as only a minimal knowledge of the IWS to create the data required for the IWS.



## 2. INTERNAL DATA STRUCTURES

As discussed above, each controller uses data structures that are specific to its particular functions. These are stored in ASCII data files located on the hard disk of each controller. There is a naming convention used for all data files that should be grouped together. The last three letters of any data file belonging to a particular group is the same for all data files in that group. For example, all CMM data files that describe the pipe clamp are given the suffix of 'clp' in the file name (i.e. pts\_clp). The letters before the suffix (i.e. 'pts' in this example) are used to define a particular set of data (points to be inspected in this case).

Each line of a data file is called a record. Each record is made up of fields, each field representing a different piece of data. The fields are distinguished by one or more spaces between them. One or more fields is defined as the key (or keys). These are used to find a particular record in the file. The remaining fields are data fields, and are retrieved when a data file is searched.



GLOSSARY

ADI        Abbreviation for the Automatic Dial Indicator.

automatic dial indicator

Instrument used to measure the distance that a spring mounted stem is depressed.

CMM        Abbreviation for the Coordinate Measuring Machine.

CMMC       Abbreviation for the CMM Controller.

CMM Origin

Top center of the gage block that is located at the SW corner of the CMM table. The probe tip is positioned here when the CMM is initialized, consequently establishing this location as the zero position for the CMM.

cold shut down

Performed when the workstation is in the warm shut down state and the operator wants to terminate the execution control system on the computer controllers and disable, but not power down, all of the workstation equipment.

continuous mode

Robot mode in which the Robot does not pause at the point it is moving to before proceeding on to the next point. The opposite is point mode in which the Robot stops when it reaches the point to which it is moving, where it waits for its next command.

controller

Supervises the operation of a mechanism, another controller, or both.

coordinate measuring machine

Machine used to measure the dimensions of a part.

data server

Software module that interfaces the controller it resides on to the data it requires.

ECS        Abbreviation for the execution control system.

elbow mode

Robot mode in which the elbow is specified to be either up or down.



execution control system

Computer program that runs on each controller computer and implements the AMRF design principles. This program loads and executes those modules which determine which controller is actually being run.

extended cold shut down

Executed after cold shut down and is used to power down all of the workstation controllers and equipment when operations are halted indefinitely.

extended warm shut down

Executed after warm shut down and is meant to disable some of the workstation equipment if operations are suspended temporarily.

FLB

Function library for the CMM. The functions and procedures contained here interface the HP computer that this module is running on to the Sheffield CMM. This module is a Pascal translation of the BASIC FLB that Sheffield provides with its CMM.

gage block

For the purpose of the IWS, the gage block used is a block of metal with a hemispherical hole in the center of its top, and glued onto the CMM at its SW corner to provide a zero position for the CMM.

gantry

A track mounted above the IWS that supports the Robot (mounted upside down), and allows the Robot to glide along it. This track gives the Robot one more dimension (along the track) than is normally provided with this Robot.

inspection workstation

AMRF workstation that inspects parts for dimensional tolerance and surface finish.

integrated mode

Mode of operation of the IWS in which the IWS is integrated to the AMRF--receiving commands from the AMRF Cell, and obtaining data from the IMDAS.

IRC

Abbreviation for the Inspection Robot Controller.

IWS

Abbreviation for the Inspection Workstation.



joint coordinated mode

A Robot mode which allows the Robot hand to move between two points in its most efficient manner. The alternative mode is straight line mode.

logical architecture

Specifies the direction of commands and statuses between controllers and between controllers and equipment.

machine mode

Robot mode that specifies what robot degrees of freedom are currently active. If machine mode is 1 (track mode), the robot can move along the gantry track. Machine mode of 0 (arm mode) allows the robot arm to move in all of its six joints.

move mode

Robot mode that specifies whether the robot arm will move in straight line mode or joint coordinated mode. Move mode 0 is the joint coordinated mode; move mode 1 is the straight line mode.

network

The connections (both hardware and software) that connects the IWS controllers together and to the rest of the AMRF. Local network refers to the former only.

operation sheet

A process plan at the workstation level--i.e. that coordinates the activity of the controllers in the workstation.

orientation mode

Robot mode (under teach pendant control) in which the Robot can move in yaw, pitch, and roll.

parallel port

Refers to a computer I/O interface in which data are transferred in groups of bits at a time.

pendant

Usually referred to as a teach pendant, it is a hand held device with keyboard and display, used by an operator to communicate with a mechanism. In the IWS, a pendant is included with the CMM, and is considered a part of it. Likewise, the IWS Robot has a teach pendant.



PH9 probe

A motorized probe used on the CMM. This probe can be oriented automatically under computer command. This allows the CMM to measure more part surfaces without reorienting the part than would be normally possible.

physical architecture

Specifies the physical connections among the controllers and equipment.

position mode

Robot mode (under teach pendant control) in which the Robot can move in x, y, and z directions.

process plan

Data file that contains a sequence of steps to perform a manufacturing task.

ready state

The state in which a controller is ready to accept work order commands. This is the normal state of the controller during its operation.

RS232 An interface that specifies the electrical and mechanical connection between two points.

safety fence

An electric eye that surrounds the Robot at the IWS and detects if an object moves into the Robot's workspace, and reacts according to its settings (either by audible alarm, blinking light, or shutting down the Robot).

serial port

Refers to a computer I/O interface in which pieces of data are transferred one bit at a time.

SRI Abbreviation for the Surface Roughness Instrument.

SRIC Abbreviation for the SRI Controller.

stand-alone mode

Mode of operation of the IWS in which an operator commands the IWS, and the data used by the IWS is stored in local data files.

straight line mode

A Robot mode which forces the Robot hand to move between two points in a straight line. The alternative mode is joint coordinated mode.



subordinate controller

Controller that is controlled by the subject controller.

supervisory controller

Controller that is the supervisor of the subject controller.

surface roughness instrument

Machine that measures the optical scattering off the surface of a part that can be correlated with its surface roughness.

transition commands

Commands used to transfer the IWS to a new state (specified by the UVA protocol [4]).

warm shut down

Performed when the workstation is in the ready state and the operator wants to discontinue operations but leave the workstation enabled.

work order commands

A command accepted by a controller when it is in ready state, and used to perform one of its main functions.

WSC

Abbreviation for the Workstation Controller.







APPENDICES

A. IWS DOCUMENTATION LIST

1. H. T. Moncarz, Architecture and Principles of the Inspection Workstation, to be published as an NBSIR.
2. H. T. Moncarz, Implementation of the Execution Control System of the Inspection Workstation, to be published as an NBSIR.
3. H. T. Moncarz and T. H. Hopp, Implementation of the CMM Controller, to be published as an NBSIR.
4. H. T. Moncarz and T. V. Vorburger, Implementation of the SRI Controller, to be published as an NBSIR.
5. H. T. Moncarz and B. Borchardt, Implementation of the Inspection Robot Controller, NBSIR 88-3772, April 21, 1988
6. S. A. Osella, Implementation of the Workstation Controller, to be published as an NBSIR.
7. J. Zimmerman, Inventory of Equipment in the Inspection Workstation, to be published as an NBSIR.
8. H. T. Moncarz, S. A. Osella, B. Borchardt, and R. Veale, Operations Manual for the Inspection Workstation, NBSIR 88-3766, April 21, 1988.
9. J. Zimmerman, Recommended Technical Specifications for Procurement of Commercially Available Systems for the Inspection Workstation, to be published as an NBSIR.







## B. OPERATIONS REFERENCE GUIDE

## 1. STARTING THE INSPECTION WORKSTATION

Turn on the Robot, SRI, and WSC computers by flipping the red main circuit switch so that it is lit. Select the Pascal Operating System for these computers. Enter the correct date and time. [Chapter IV, §1.1]

Turn on the CMM computer by pressing the ~AC LINE button on the front of the computer keyboard. Enter the correct date and time. [Chapter IV, §1.2]

Turn on the CMM by shifting the Power On lever to the right and then pressing the Ready/Servo On button. [Chapter IV, §2.1.1]

Calibrate the PH9 Probe if necessary. [Chapter IV, §2.1.2]

Position the CMM probe tip in the gage block. [Chapter IV, §3.1]

Turn on the Robot System by turning the switch on the box on the east gantry column to on, pressing the power on button on the control box on the west column, and finally pressing the battery low button also on the west control box. Wait for the AM Smart Robot Operating System to load. [Chapter IV, §2.2.1]

Calibrate the Robot Arm. [Chapter IV, §2.2.2]

Calibrate the Robot Track. [Chapter IV, §2.2.3]

Load the Robot Program. [Chapter IV, §2.2.4]

Clear the Serial Port. [Chapter IV, §3.2.3]

Start the Robot Program. [Chapter IV, §3.2.4]

Press the 0 button on the Dial Indicator so that the display shows all zeros. [Chapter IV, §2.4]

Start the Execution Control System on the CMM Controller. When the message Press Execute to Continue appears on the CMM monitor, press the servo on button on the CMM console, press the AUTO button on the hand pendant, and finally press the EXECUTE button on the computer keyboard. [Chapter IV, §4.1]

Start the Execution Control System on the SRI Controller. When the message Press M Button appears on the SRI computer monitor, press the M button on the Dial Indicator. [Chapter IV, §4.2]



Start the Execution Control System on the Robot Controller.  
[Chapter IV, §4.3]

Start the Execution Control System on the WSC. Wait for the Network Established message. [Chapter IV, §5.2.1]

Press 3 [ENTER] to Synchronize the Workstation. Wait about 30 seconds. [Chapter IV, §5.2.2]

Press 3 [ENTER] to warm start up the Workstation. [Chapter IV, §5.2.3]

## 2. OPERATING THE INSPECTION WORKSTATION STAND-ALONE

At the Workstation Controller computer, select the Work Order option in the main menu by pressing 3 [ENTER]. [Chapter V, §2.2.1]

Press 9 [ENTER] to read the work order data from a file. Enter the name of the script file for the tray in the tray station. For example, type SCRIPT1 [ENTER] for Tray 510, etc. [Chapter V, §2.2.1.1.1]

Press 10 [ENTER] to issue the work order. [Chapter V, §2.2.1.5]

## 3. RESTARTING THE INSPECTION WORKSTATION

Stop the Execution control system on each of the computer controllers by pressing the Shift and Stop (printed in blue) keys together. Then press the I key to initialize the computer.

On the CMM hand pendant, press MAN, JOY, and SLOW and use the joysticks to move the CMM probe tip to the gage block. [Chapter IV, §3.1]

Using the Robot hand pendant, stop the Robot program by flipping the rocker switch on the pendant to STOP briefly, and putting it back to RUN position. Then press IMM to go back to manual mode. Lastly, press Machine 0 [ENTER] MVM 0 [ENTER] to enable arm movement mode. [Chapter IV, §3.2.1]

Move the Robot to the arm calibration position by pressing MOV 199 [ENTER]. [Chapter IV, §3.2.2]

Clear the Serial Port and start the Robot Program. [Chapter IV, §3.2.3]

Start the Execution Control System on the CMM Controller. When the message Press Execute to Continue appears on the CMM monitor,



press the servo on button on the CMM console, press the AUTO button on the hand pendant, and finally press the EXECUTE button on the computer keyboard. [Chapter IV, §4.1]

Start the Execution Control System on the SRI Controller. When the message Press M Button appears on the SRI computer monitor, press the M button on the Dial Indicator. [Chapter IV, §4.2]

Start the Execution Control System on the Robot Controller. [Chapter IV, §4.3]

Start the Execution Control System on the WSC. Wait for the Network Established message. [Chapter IV, §5.2.1]

Press 3 [ENTER] to Synchronize the Workstation. Wait about 30 seconds. [Chapter IV, §5.2.2]

Press 3 [ENTER] to warm start up the Workstation. [Chapter IV, §5.2.3]

Go back to Appendix B.2. to operate the IWS.

#### 4. SHUTTING DOWN THE INSPECTION WORKSTATION

At the Workstation Controller computer, select the Warm Shutdown option by pressing 4 [ENTER]. Wait about one minute for the Workstation to complete the warm shut down. [Chapter VI, §2.1]

Subsequently, also at the Workstation Controller computer, select the Cold Shutdown option by pressing 4 [ENTER]. [Chapter VI, §4.1]

Wait about one minute then press the Shift and Stop (printed in blue) keys together to stop the execution control system. Then press the I key to initialize the computer. [Chapter VI, §4.3]

Stop the Robot program by flipping the switch on the pendant to STOP briefly, and putting it back to RUN position. Then enter IMM to go back to manual mode. [Chapter VI, §4.4.1]

Press Machine 0 [ENTER] and then MVM 0 [ENTER] to make the Robot arm movement active. Press MOV 199 [ENTER] to move the arm into calibration position. [Chapter VI, §4.4.2]

Press Machine 1 [ENTER] to activate the Robot track movement. Press MOV 950 [ENTER] to move the gantry into calibration position. [Chapter VI, §4.4.3]



Turn off each of the computer systems by flipping the outlet's red switch so that the light goes off. Turn off the CMM computer by pushing the button in the front of the computer keyboard.  
[Chapter VI, §5.1]

Power down the Robot by turning off the switch on the box on the east column of the Robot gantry. Then push the red power off button on the control box on the west column so that it locks on the catch. [Chapter VI, §5.2]

Turn the CMM servos off by pressing the Servo Off button.  
[Chapter VI, §5.3]



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<b>4. TITLE AND SUBTITLE</b>  "Operations Manual for the Inspection Workstation"			
<b>5. AUTHOR(S)</b> Howard T. Moncarz, Stephen A. Osella, Bruce Borchardt and Ralph Veale			
<b>6. PERFORMING ORGANIZATION</b> <i>(If joint or other than NBS, see instructions)</i>  NATIONAL BUREAU OF STANDARDS U.S. DEPARTMENT OF COMMERCE GAITHERSBURG, MD 20899		<b>7. Contract/Grant No.</b>  <b>8. Type of Report &amp; Period Covered</b>	
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<input type="checkbox"/> Document describes a computer program; SF-185, FIPS Software Summary, is attached.			
<b>11. ABSTRACT</b> <i>(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)</i> <p>This document describes the operation of the Inspection Workstation (IWS) of the AMRF. The IWS uses a coordinate measuring machine for dimensional metrology, an optical roughness gage for surface finish inspection, and a robot for part handling within the workstation. Each of these three pieces of equipment is supervised by a separate controller, and a fourth controller (the workstation controller) coordinates these equipment controllers.</p> <p>The IWS can receive its commands either from the AMRF Cell Controller or from the keyboard of the IWS workstation controller. The detailed instructions for starting the IWS and maintaining its operation in either of these two modes are provided in this document.</p>			
<b>12. KEY WORDS</b> <i>(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)</i> AMRF; coordinate measuring machine; dimensional tolerance; Inspection Workstation; surface finish; surface roughness			

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